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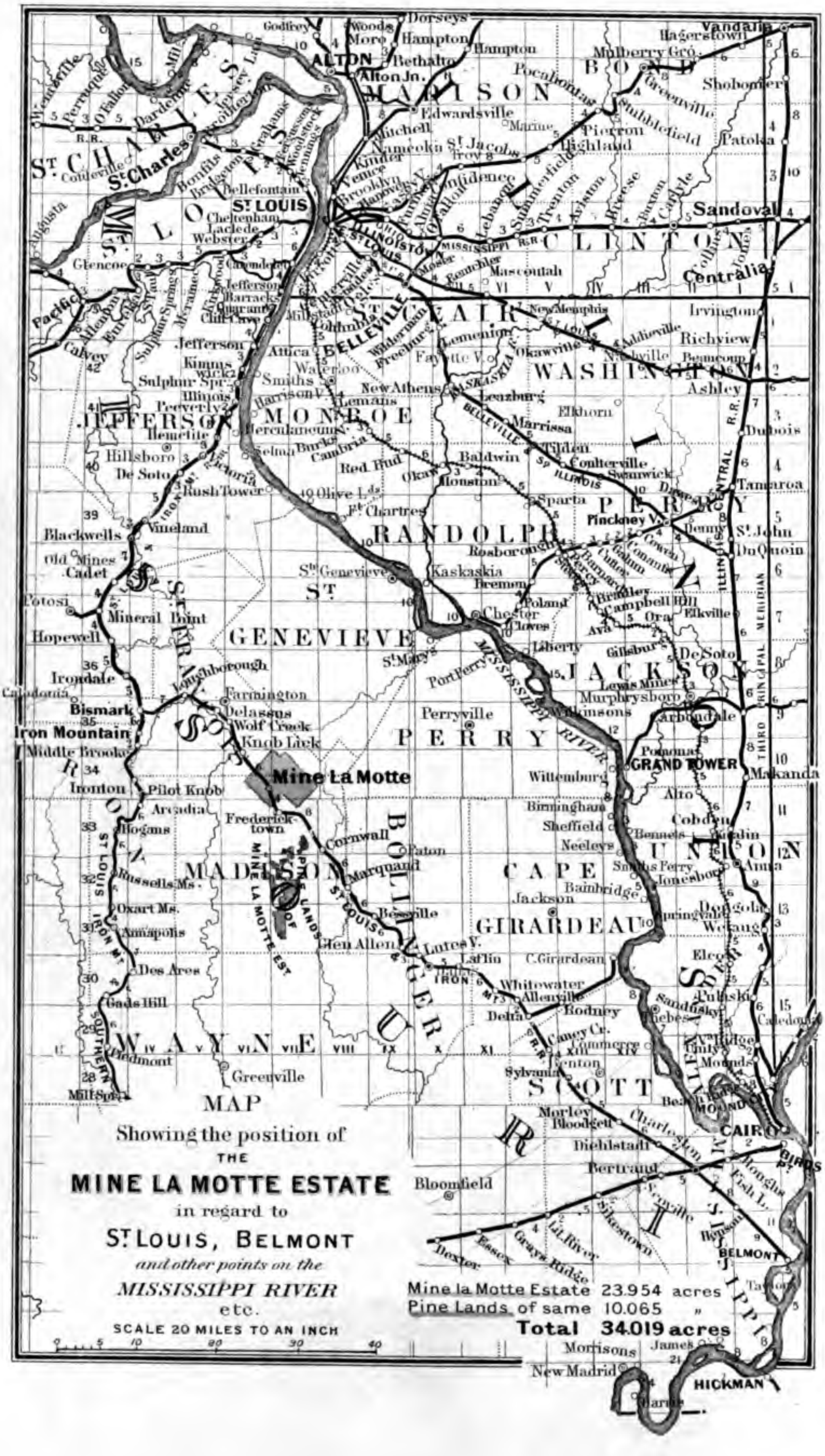

MAP

Showing the position of

THE

MINE LA MOTTE ESTATE

in regard to

ST LOUIS, BELMONT

and other points on the

MISSISSIPPI RIVER

etc.

SCALE 20 MILES TO AN INCH

Mine la Motte Estate	23.954	acres
Pine Lands of same	10.065	"
Total	**34.019**	**acres**

GEOLOGICAL REPORT

ON THE

MINE LA MOTTE ESTATE

THE PROPERTY OF

HON. ROWLAND HAZARD

SITUATED IN

MADISON COUNTY, MISSOURI

WITH ACCOMPANYING MAP AND DIAGRAMS

BY

JAMES E. MILLS, B.S.

CONSULTING GEOLOGIST

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To Mr. Wm. B. Cogswell, C. E., *Agent for*

Hon. ROWLAND HAZARD,

Dear Sir:

To make clear the position, character, and extent of the deposits of lead ore on the Mine la Motte tract, I will first describe the general geology of the tract. It is shown in detail on the general map accompanying this report, but its principal features fall more readily under one view in the accompanying Diagram No. 1 and Section No. 1.

General Geology.

The rocks exposed on the estate and in the neighborhood are comprised in five distinctly-marked groups, as shown in Section No. 1; but these groups are naturally classed in two great divisions, one, comprising the lowest group only, consists of crystalline rocks (with stratification obscured, if any exists), and the other, comprising the three higher groups, consists of distinctly stratified rocks.

Crystalline Rocks, or Porphyry

The crystalline rocks are made up principally of feldspar crystals in a feldspar paste or matrix, and are, therefore, porphyries, though usually called granite. Their prevailing colors are shades of red, from pink or flesh color to dark purplish slate color, but some are gray, almost white. There is frequently a green chloritic mineral scattered through the porphyry. I have seen grains of iron pyrites and magnetic iron ore in it, but they formed a very small proportion of the mass. No lead ore or other ore of value has been found in these rocks, on the tract or in the immediate neighborhood, although about eighteen miles west from here are the great iron ore masses of Iron Mountain and Pilot Knob, in similar rocks.

Dykes of Doleryte.

Topography of the Porphyry.

Nonconformability of Porphyry with overlying rocks.

The porphyries are traversed in places by dykes of doleryte. One such occurs in the mass on Rock Creek Plot, N. 13, W. 13, and one at the anticlinal axis on Mine Creek Plot, N. 6, E. 4., *and pieces were found loose in several places within the area of porphyry outcrop, southeasterly from this point; and also within the one southwest of the Jack Diggings. The porphyries present a broken, hilly surface wherever exposed, so much so as to be unfit for agriculture; and there are no farms, or very few, on the areas where they outcrop, except at the river bottoms. They had been upheaved, and carved into hill and valley by erosion, before the other rocks were deposited upon them, and so their upper surface is not parallel to, and does not continuously conform with, the lower surface of any one stratum resting upon it, but they protrude up into and through the overlying strata; therefore the latter not only lie upon the porphyry, but abut against the hills of it, and rest in the valleys carved out of it. This, however, is proved only of the two lower of the four groups of stratified rocks. The porphyry does not show itself, on the estate, in contact with strata of the two higher groups.

Stratified rocks and their conformability.

The uncrystalline rocks of the four upper groups were deposited by water in horizontal strata, successively, without any intervening extensive denudation. They were afterwards thrown into undulations by upheavals, and in places broken; but they lie in parallel planes, and each stratum comes in contact only with two others, one overlying and the other underlying it, except at faults to be below described. In geological phraseology, they are "conformable." They belong to the Silurian period.

Designation of Groups of Strata.

I will designate these groups as follows, beginning with the lowest:—*Lower Sandstone Group; Lead-bearing Group; Massive Magnesian Limestone Group; Cherty Group.*

Lower Sandstone.

The lowest of the four, and the one next succeeding the crystalline rocks in upward series, consists of sandstones made up of quartz, and very little else except, at times, enough oxides of iron to give them rust-colors when weathered. The quartz is beach sand with its grains arranged as the ocean waves left them, so that nearly every exposed section shows "false bedding," or beach structure, which may often readily be mistaken for the stratification if the observer is not on his guard. They yield a poor soil, and where they outcrop* there are few farms except the bottom lands and places where some constituents of the soil have been left from limestone strata which formerly overlay the sandstones.

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* In the Report of Geological Survey of Missouri, 1874, this dyke is said to traverse sandstone altered to quartzite. I think a peculiar gray porphyry was mistaken for quartzite. I have seen no dyke penetrating any of the strata higher than the porphyry.

Thickness of the Lower Sandstones.

The thickness of these sandstones is not determined, and on account of the unevenness of the porphyry floor upon which they rest, it is difficult to form even an estimate of it. A diamond drill was sunk 160 feet in them at one place (see Appendix A, pp. 25, 26†), without reaching the porphyry below. We know, therefore, that the whole group comprises a thickness of at least 160 feet, but cannot estimate how much thicker it may be.

Absence of Lead Ore in Lower Sandstones.

No lead or other ore of value has been found in these rocks, and there is no probability of finding any which would render it judicious to undertake any exploration by drilling or otherwise.

Lead-bearing Group.

The next group in ascending order—the Lead-bearing Group—consists of limestones, sandstones, and slates, with oxides of iron and manganese, and contains the lead ore and other sulphides associated with it. It averages about 76 feet thick. It will be treated of fully below, and I will omit any further description of it here.

Massive Magnesian Limestone Group.

The next group—the Massive Magnesian Limestone Group—consists of magnesian limestones, generally massive or heavy

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"Outcrop" and "Exposure."

* By "outcrop" is meant that portion of a stratum or group of strata not overlaid by other rocks in place. The outcrop is generally covered with loose materials—earth, stones, &c. An outcrop with no loose materials resting upon it is an "exposure."

† The Appendices A and C attached to the original report are not printed herewith, and the pages given refer to the manuscript. A short memorandum of what they contain will, however, be found at pages 44 and 51. Appendix B is given in full at page 45.

bedded, of a uniform, compact texture; of light gray or white color toward the top of the series, and, towards the bottom, of various shades of drab, with blotches of darker drab or of a greenish or warm yellow color, the change in color being due to an increase in the proportion of iron oxides toward the bottom, where it is sometimes so large as to render the soil produced from it nearly as red as that from the Lead-bearing Group.

SANDSTONE IN MASSIVE MAGNESIAN LIMESTONE GROUP.

There is a sandstone in places, in this group, not forming a constant stratum of sandstone, but patches or irregular-shaped masses in a stratum of limestone. It is about 27 feet above the bottom of the group, and is exposed as shown on the large map in Plot N. 6, E. 9, and N. 6, E. 10, and north and west of the Rattlesnake Diggings, and on the left bank of Village Creek in Plots N. 4, E. 13, and N. 5, E. 13, and I think it is probably the same which is exposed near the Copper Mines in S. 5, W. 12. The exposures are only of loose fragments, except the more northerly ones on the bank of Village Creek, where one or more masses of the sandstone occur in place.

The magnesian limestones of the group yield good soils. Nearly all the farms of the estate are on the out-crops of this and the Lead-bearing Groups.

ABSENCE OF LEAD ORE IN MASSIVE MAGNESIAN LIMESTONE GROUP.

No lead ore, or other ore, has been found in the strata of this group, except one piece of galena weighing a few pounds, which is reported to have been found on Round Hill, back of the lime-kiln in Plot N. 15, E. 9, and which may have come from either this or the next higher group.

The exposures of the rocks of the group are numerous and extensive. I saw no indications of lead ore in them, and this, with the fact that none (except, possibly, the piece just mentioned) has been found in them, precludes any probability of valuable discoveries such as to warrant any considerable expenditure for exploration among these rocks.

The thickness of the group, as nearly as I can determine, is 135 feet. The estimate has to be based on exposures of top and bottom of the group, which are from one-half a mile to a mile apart, with a long interval without exposure, and although checked in several ways, must be considered as an estimate with a small margin for probable error.

CHERTY GROUP.

TOPOGRAPHY OF CHERTY GROUP.

The last and highest group of strata found on the estate—the Cherty Group—presents very few exposures. The areas where these strata outcrop are always hilly. The surface is a succession of steep slopes, paved or riprapped with loose chert or flint, completely hiding the strata from which it was derived.

EXPOSURES OF CHERTY GROUP.

I will mention here the few exposures of the rocks in the group, in place, found during the survey, as there will not be occasion to return to the subject again.

In the brook above the fault, in Plots N. 11, E. 6, and N. 11, E. 7, and N. 12, E. 7, are exposed thin-bedded limestones, some of them having a fine silicious grit, and, at head of the exposure, clay from disintegration of slate. At the brook above the fault in N. 10, E. 6, and N. 11, E. 6, are found similar clays, and on being dug into, they prove to be mixed with fine disintegrated silica, and to rest on limestone with fine silicious grit. Similar clays and disintegrated powdery silica, with pieces of chert and limestones with fine grit, are exposed in Little Rock Creek, in Plots N. 22, E. 2, and N. 22, E. 3. These all lie at and near the base of the series; and similar limestones are exposed at the base of the series on Round Hill, in Plot N. 15, E. 9; and from 65 to 70 feet higher is exposed a light yellow limestone with little drusy cavities. On Mine Creek, in Plots N. 9, E. 10, and N. 10, E. 10, limestones with fine grit, and in N. 10, E. 9, clay belonging to the group, are exposed; and on the most easterly branch of Village Creek, in Plot N. 2, E. 16, there is an exposure, 26 feet thick, or more, of light yellow limestones, with yellow powdery fracture and with frequent little drusy cavities, and containing in some layers fine silicious grit, which belong to this group, and probably rest far above the base of it.

GENERAL CHARACTERISTICS OF CHERTY GROUP.

From the exposures and from the layer of loose chert paving the whole surface over the outcrop, I conclude that the strata of the group consist of limestones, more or less silicious, with chert, and in places (near the base of the series, at least), clay slate and powdery silica. The chert exists, probably, here as elsewhere, in layers of varying thickness and irregular masses imbedded in the limestone. It is much less readily affected by decomposing and disintegrating agencies than the limestone and clay-slate, and therefore where the latter have been removed in solution and suspension by the waters which have excavated the valleys, the chert has been left near the edges of the strata acted upon. It has also rolled further down the slopes, and portions of it are found scattered over a broad belt around and beyond the area now occupied by the group, where they are undoubtedly the remains of strata which have been carried away.

THICKNESS OF THE CHERTY GROUP.

The thickness of the group can nowhere on the estate be measured with accuracy, but at Big Hill, in Plots N. 19, E. 6, and N. 19, E. 7, I estimate that there is a thickness of 276 feet of these strata, with but a small margin for probable error; and this is probably the greatest thickness found on the estate, except, possibly, on the extreme eastern portion of it.

NO CONSIDERABLE DEPOSIT OF ORE YET FOUND IN THE CHERTY GROUP.

I have heard of no lead or other ore found in this long series of strata except the piece of galena above mentioned, on Round Hill, and some small pieces which I found on a ledge on the eastern branch of Village Creek, Plot N. 2, E. 16, where they had been placed by some one who probably found them in the neighborhood. The galena was attached to pieces of the yellow limestone of the group which is exposed at that place.

POSSIBLE EXISTENCE OF LEAD ORE IN THE CHERTY GROUP.

The fact that so few discoveries of lead ore have been made in the strata of this group does not exclude the possibility of the existence of large masses of it, because the outcrops are so generally concealed by loose flints. Moreover, some of the higher members of the series have yielded lead largely elsewhere in Missouri. But while exploration can be carried on with every reasonable probability of success in the Lead-bearing Group it would not be advisable to undertake it in this group with only a possibility of valuable discoveries.

EXPOSURES AND OUTCROP OF STRATA.

The exposures of the rocks of the different groups are shown in colors on the General Map wherever their position has been determined by survey. By far the greater part of the outcrop of the different groups is concealed under soil and other loose material, and the area of outcrop of any given stratum or group have to be deduced from the dip and strike* or trend of the strata where exposed, together with the contour of the surface, and with some aid from the loose stones and earth over the outcrop which indicate the kind of underlying rock. The areas of outcrops of the different groups thus deduced are designated on the General Map and annexed Diagram No. 1, by tints and colored lines.

POSITION OF STRATA SHOWN BY CONTOUR LINES ON THE MAP.

The course and consequent depth from the surface of any stratum, where it is overlaid by other rocks, has also to be deduced from the dip and strike or trend, at exposures of it and other strata. The position of the lead-bearing beds is shown for considerable areas on the General Map, and on the Special Maps of Mines, by colored contour lines. But the systems of upheaval and consequent dip and strike or trend of the strata will indicate, in a general way, definitely enough to be of great service in exploration, the trend and depth below the surface of any given stratum far beyond where it is practible to determine it accurately; and therefore, before passing to a detailed account of the Lead-Bearing Group I will describe the systems of upheaval† by which the strata and included ore deposits have been put into their present position.

UNDULATIONS OF STRATA AND FAULTS.

The strata were deposited, as already stated, horizontally, and have since been curved and bent into gentle, low undulations, and have also been broken along certain lines, and abruptly uplifted on one side of the fracture or downthrown on the other.‡

GEOLOGICAL TERMS: "STRIKE," "DIP."

* The "strike" of a stratum is the direction of a horizontal line on one of its broad surfaces, and the "dip" of a stratum is the descent of one of the broad surfaces in the direction of greatest descent, and the "angle of dip" is the angle made by a line on the surface in the direction of greatest descent with a horizontal line on the same vertical plane. The "line of strike" is a contour line on one of the broad surfaces of a stratum, or a line parallel to the edge of water standing against the surface; and the "line of dip" is the line which water would follow if flowing over the surface. (See Diagrams Nos. 2, 3, 4.)

† "Stratigraphy," in technical language.

"ANTICLINAL AXIS," "SYNCLINAL AXIS," "FAULT."

‡ The crest of any arched stratum is an "anticlinal axis;" the lowest line along the trough of a stratum is a "synclinal axis:" the dip is therefore away from the "anticlinal axis" on both sides, and toward the "synclinal axis" on both sides. A fracture and displacement of strata by uplift on one side of the fracture or downthrow on the other is called a "fault." (For illustration of "anticlinal" and "synclinal axis," and "fault," see Diagram No 2.)

One and the principal system of undulations has its axis in a northwesterly southeasterly direction (N. 38° W., to N. 57° W.), and another in a northeasterly southwesterly course (N. 28° E., to N. 30° E., in cases where it has been determined). The Great Faults are parallel to the axes of the northwesterly southeasterly undulations.

OUTCROP OF LOWER SANDSTONES. GENERAL STRATIGRAPHY.

The outcrop of the Lower Sandstones occupies the middle part of the tract. The surface is lowest within this area of outcrop of the Lower Sandstones, and the Little St. Francis River, which drains the whole estate except the extreme eastern corner, flows across and meanders through it; but the lower elevation here is due to denudation; any given one of the strata remaining has a higher average elevation within this area than either to the northeast or southwest. The area narrows toward the southeast, and the outcrops of the higher groups approach one another from the northeast and southwest, and in fact beyond the boundary of the estate they meet and pass around the southeast end of the area of outcrop of the Lower Sandstones. This is because the undulations drop, or die out toward their southeast end.*

FAULT C-D, AND CREST OF ONE OF TWO HIGHEST UNDULATIONS.

It will be noticed that the northeasterly boundary of the area is a sharply defined line running straight for long distances. This is a line of fracture (green line C–D on the Map and Diagram No. 1), with a great uplift on the southwesterly side, which brings the edges of the sandstone up so as to abut against the edges of higher groups. I have been able to measure the extent of the uplift at only one point; namely, near its crossing with Big Rock Creek, and find it to be 104 feet (with a small margin for possible error), bringing the upper part of the Lower Sandstone into contact with the lower part of the Massive Magnesian Limestone Series. The uplift or downthrow probably lessens going southeast, and at the crossing of the most easterly branch of Village Creek it probably passes into a steep dip to the northeast without fracture.

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* When the anticlinal axis is horizontal the lines of strike on both slopes are parallel, but when the axis drops toward one end the lines of strike from the two sides approach one another. (See Diagrams No. 3 and No. 4.)

Crest of another of the Principal Undulations and Faults.

Two isolated patches of sandstone appear outcropping away southeast of the main area; one south of the Bluff Diggings and one at the West Branch of Village Creek, both accompanied with outcrops of porphyry. These sandstones are brought up partly by fracture and abrupt uplift, and partly by gradual rise of the strata. Several of the fractures and uplifts appear in the Bluff Diggings: one or more crosses the West Branch of Village Creek, in Plot S. 2, E. 7, and the main Village Creek in Plot S. 5, E. 11, but the uplift at either or all of these faults, is much less than at the Great Fault before mentioned.

The strata reach their highest observed elevation along and near two lines, one passing through these two isolated patches of exposed sandstone, and continuing, with some changes of course, northwesterly to the boundary of the tract (see Map and Diagram, line A–B), and the other along or near the Great Fault above mentioned on its southwesterly side (see green line C–D on Map and Diagram No. 1).

Undulations lower towards the southwest as well as northeast.

From the first-named line the undulations are successively lower going southwest, and in the neighborhood of the Copper Mines the higher groups come in and overlie the sandstones.

Undulations between two highest Crests.

The undulations between these two highest crests will be described in detailed account of the Lead-bearing Group.

Lowest Synclinal on the tract.

Northeast of the Great Fault above named (C–D on Map and Diagram No. 1) there is a synclinal or bottom line of a trough of the undulations which is the lowest one on the tract, and from which the undulations rise both to the southwest and northeast. Where this line (E–F on Map and Diagram No. 1) crosses Little Rock Creek, Plot N. 22, E. 2, the strata drop to their lowest position by a fracture and downthrow on the northeast side, of 140 feet or more, which brings the lower part of the Massive Magnesian Limestone Group against the lower part of the Cherty Group, edge to edge. The fault continues northwesterly to and beyond the boundary of the tract, but going southeast it passes into a synclinal axis, and as such crosses Big Rock Creek, and probably continues southeasterly. The faults of this N.W.–S.E. system die out, like the anticlinals, towards the southeast; in other words, the number of

Strata dropped to their lowest position by Fault.

Faults of N.W.-S.E. System decrease going southeasterly.

Additional Faults of N.W.-S.E. System.

faults increases going northwestwardly, and the uplift at each increases in the same direction. One fault crosses Little Rock Creek, in Plot N. 20, W. 1, and another was found, but not traced far, in Plot N. 24, W. 1.

Rise of Strata towards N.W. by Undulations of N.E.-S.W. System.

The rise towards the northwest, on the eastern part of the tract, is not by continuous ascent of the strata in that direction, but in undulations, each carrying its crest higher than the one next southeast. The axes of the undulations have a trend, as far as observed, of N. 28° E., to N. 30° E.

Anticlinals of N.E.-S.W. System.

One of the anticlinals, or crests of undulations, of this group forms the westerly rim of the Jack Diggings basin (K–L on Diagram No. 1 and Map). It dies out southwestwardly, and its influence has not been observed beyond the Seed Tick Diggings. Another (M–N on Diagram and Map No. 1) brings up the sandstones west of the Golden Vein and Wild Cat Diggings, and between them and the outcrop of limestones in the Copper Mine neighborhood. It drops northeasterly so as to let the outcrop of the Lead-bearing Group pass around and over it, and project westward like a great bay into the area of sandstone outcrop. Another anticlinal of this N.E.-S.W. system (O–P on Map and Diagram No. 1) passes through the western end of the Copper Mine, or, rather, the Copper Mine, after following along its southwesterly slope, is turning to pass over its crest, which is then falling southwestwardly.

General Characteristics of Undulations and Dips.

The undulations are gentle and wavering in direction, and the dips, with few exceptions, low, more often under than over 4°; and the position assigned to the axes is only approximately correct, but sufficiently so to be of service in illustrating the position of the strata.

Faults of N.E.-S.W. System.

There are also faults connected with these northwesterly-southwesterly undulations, and the strata and lead deposits of the Golden Vein get their position by one or more breaks or faults running from N. 28° E., to N. 30° E., which will be noticed in the detailed account of the lead ore deposits.

Limits of the Rise of Strata towards the N. W.

I have spoken of the rise of the strata to the northwest. On the northeast side of the lowest line above mentioned (E–F on Map and Diagram No. 1) there is a descent going northwest between Big Rock Creek and Little Rock Creek, for the top of the Massive Magnesian Limestone Group at the Round Hill exposure (Plot N. 15, E. 9,) is 83 feet higher than it is on the northeast side of the fault at Little Rock Creek, in Plot N. 22, E. 3. The rise towards the northwest therefore lessens going northeast, and perhaps ceases at the lowest N.W.-S.E. line (I-J on Map and Diagram No. 1).

UNDULATIONS OF N.E.-S W. SYSTEM DIE OUT IN DIRECTION OF BOTH ENDS.

The undulations of the N.E.-S.W. system drop or die out towards both ends, and those of the N.W.-S.E. system towards their southeast end, and the uplifts by faults of this system lessen or die out in the same southeasterly direction.

GENERAL RESULT OF THESE SYSTEMS OF UNDULATIONS.

The general result of the whole series of undulations and uplifts may be compared to the effect of one great anticlinal axis with a southeasterly direction, dying out or dropping southeastward (see Diagram No. 4). The area of outcrop of each group projects forward in a southeasterly direction, and passes around the southeasterly end of the area of outcrop of the next lower group, and, in turn, the outcrop of the next higher passes around it.

LIMITS OF AREA OF STRATA ON THE TRACT.

Where any group outcrops, none of the higher groups remain. The Lead-bearing Group, for example, is not to be found anywhere in the area of porphyry or lower sandstone outcrops. But where any group outcrops, all the lower ones are in place below it, except where the porphyry protrudes through them. Therefore the Lead-bearing Group not only covers the areas where it outcrops, but spreads out under the higher groups wherever they exist, except where porphyry protrudes; and as this is the most important group, I have represented, on the General Map and on Diagram No. 1, the whole area on which it rests with one tint, and have represented the higher groups with colored lines through which the tint of the Lead-bearing Group shows itself,* except at exposures, which are all represented by surfaces, not lines, of color. The area of outcrop of the Lead-bearing Group is shown by the

AREA OCCUPIED BY LEAD-BEARING GROUP.

METHOD OF REPRESENTING LEAD-BEARING GROUP AND OVERLYING GROUP ON THE MAP.

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* This description refers to the original drawings. It has been found necessary to adopt another designation on the printed Map and Diagrams, which will be plain in examination.

tint alone, and the area where the group is overlaid by other strata, by the same tint with the lines denoting the overlying strata. A part of the tinted surface is dotted over with brown. The dotting represents, not overlying strata, but certain characteristics of portions of the Lead-bearing Group at the areas so designated, which will presently be described.

LEAD-BEARING GROUP.

The Lead-bearing Group comprises a thickness varying from 68 to 85 feet, perhaps averaging 76 feet.

SUBGROUPS IN LEAD-BEARING GROUP.

It is naturally divided into two very distinct sub-groups. The lower of the two comprises 54 feet of thickness from the top of Lower Sandstone upwards, and the other the remaining 22 feet.

The whole group changes exeeedingly from area to area. I will first describe the subgroups as they exist where they have yielded lead.

Both consist principally of limestone, the lower one of silicious, and the upper one of slatey or argillaceous limestone.

LOWER SUBGROUP, LEAD-BEARING GROUP.

The silica in the lower group has a peculiar form. It exists in little round grains, generally visible to the naked eye, but more distinctly seen through a lens of small magnifying power. They resemble small fish-eggs, and rocks characterized by such grains are called oolitic. The proportion of limestone paste and silicious oolitic grains varies from a total absence of of the latter to a proportion so large that the rock is a hard limey oolitic quartzite, which breaks with a sharp angular fracture. Besides silica, there occurs quite commonly a chloritic mineral, forming green surfaces, and at times making, with the silica, a green sandy-looking layer of some inches in thickness. The prevailing color of these rocks is white to light gray, the quartzite often with a yellowish tinge, but in places portions of the strata are dark drab. The upper sub-group is probably more or less argillaceous throughout its thickness. When it decomposes it makes a clayey soil, and there are layers of slate (see Sections 8 and 9) in it, varying in number and thickness. The prevailing colors of the rock toward the bottom of the subgroup are blue and bluish drab or stone gray, weathering to dark drab. The slates are of a dark slate color, and they

UPPER SUBGROUP, LEAD-BEARING GROUP.

weather to a thinly laminated condition and a greenish yellow color, and are often found in this condition in the ochres where the limestone has been decomposed. Toward the top the bluish and stone gray colors yield, in part or wholly, to light gray with yellowish tinge; and these lighter colors, on weathering, frequently become variegated with warm yellow or greenish blotches.

POSITION IN THE SERIES OF THE BLUFF AND JACK BEDS.

The mineral contents, including lead ore, of the group, I will describe in detail below, only here noticing that the "Bluff" ore-bed is in the lower subgroup about 23 to 30 feet above its lower surface, and the "Jack" ore-bed is at the bottom of the upper subgroup; see Sections.

LEAD-BEARING GROUP DIFFERS IN CHARACTER ON DIFFERENT AREAS

STRATA OF LEAD-BEARING GROUP SANDY IN CERTAIN AREAS.

SANDY STRATA OF LEAD-BEARING GROUP; CHARACTERISTICS OF THESE STRATA.

The group maintains its general characteristics as just described about all the mines and open excavations where lead ore has been obtained, and over a large area (to be hereafter more particularly defined) between the Mines and Village Creek and the southern boundary of the property; but from the Seed Tick Diggings and the Jack Diggings westward and northwestward to the outcrop of the Lower Sandstone, and to the northwest boundary of the property, the strata, or a part of them, assume a very different character, which is indicated on the Map and Diagram No. 1 by dotting with brown color on the tint assigned to the group and, at exposures, by surfaces of the same brown color. The limestones become largely replaced by sand (not oolitic) mixed with ochrey oxides of manganese and iron, and quite commonly containing grains and pieces of feldspar, chlorite, &c. At times, the sand and feldspar form a fine conglomerate or breccia. The stratification is preserved, and there is no beach structure or false bedding. They differ very decidedly from the Lower Sandstones, where beach structure or false bedding prevails and commonly conceals or obscures the stratification, and where the sand is free from any large proportion of feldspar grains or other accompanying ingredients.

ORDER OF CHANGE FROM LIMEY TO SANDY CHARACTER OF LEAD-BEARING GROUP.

The change from prevailing limey to sandy character begins, so far as observed, at and near the bottom of the group, and at and near the horizon of the Jack bed. The strata at and near the top of the group, and those between the Jack and Bluff beds, preserve their limey character the longest. The limestones of the lower subgroup have, perhaps, more oolitic silica where the sandstone occupies a large part of the group, than where there is little of it. The slates of the upper subgroup are exposed in several places imbedded between these sandstones, and the sandstones and ochres of the upper subgroup are commonly more or less clayey, sometimes passing into clayey and ochrey sandstones; and so the two subgroups preserve, to some extent, their distinguishing characteristics, even after the limestone has been largely replaced by sandy material.

BOUNDARIES BETWEEN AREAS WHERE SANDY AND LIMEY CHARACTERISTICS PREVAIL.

SANDSTONES OF THE GROUP WEST OF SEED TICK DIGGINGS.

SANDSTONES OF LEAD-BEARING GROUP IN AND NEAR JACK BASIN.

ILLUSTRATION OF CHANGE FROM SANDY TO LIMEY CHARACTER IN MINE CREEK.

In the western part of the Seed Tick Diggings, the strata of the horizon of the Jack bed have become a fine conglomerate, or breccia, of sand and feldspar grains, &c., with some lime paste, which latter, however, lessens going west until it disappears. At the eastern part of the Jack Diggings the strata overlying the Jack bed are sandstones, and there is ochrey sandstone among the overlying decomposed material in the southerly and westerly part of the Jack Diggings. In the south and southwest, and west and northwest parts of the Jack basin, the strata of the group are largely sandstones. Mine Creek, which crosses the basin and exposes the rocks where it cuts through its western rim, shows the character of the change well. Sections No. 10 and 11 are made from the exposures which are shown on the Map: No. 11 from exposures on the west slope of the Jack basin, No. 10 from exposures on the west side of the anticlinal axis which forms the northwesterly rim of the basin. Right at the anticlinal the porphyry protrudes up through the lower sandstones. Going west from this exposure of porphyry, the proportion of sandstone decreases as far as to the next synclinal axis, Plot N. 6, E. 3, and in the course of the outcrop from which the Section is taken, 15 feet of the strata lying between the horizons of the Jack and Bluff beds, change from being all sandstones near the porphyry, and become mostly limestones at the portion of the exposure farthest from the porphyry near the synclinal axis. It is noticeable, also, that the strata become more sandy near the porphyry south and east of the Jack Diggings. But a large proportion of sandy strata characterizes the strata of the group at their outcrop, all the way from here to the northwest line of the estate, where there are no exposures of porphyry, while the strata preserve their limey character around the exposures of porphyry further south. The proportion of sandy strata in the group, therefore, depends partly upon nearness to protruding masses of porphyry, and partly upon other conditions not known, probably the direction of the currents in the water from which the strata were deposited. In general, it may be said that the proportion of sandy strata decreases southward from the Great Fault which extends across the property, and is marked C–D on the Map and Diagram No. 1.

Conditions which determine the Sandy or Limey character of Lead-bearing Group.

Decrease of proportion of Sand in the Group southward from the Fault C-D.

North of the Fault the strata of the group have the sandy character, except a few feet at and near the top of the group, wherever they outcrop, all the way to the northwest boundary of the tract. How far east this continues there are no means of judging without exploration by drilling or sinking shafts, as the strata of the group are buried under those of the higher groups.

General Sandy character of the strata of Lead-bearing Group at the Outcrop north of Fault C-D.

It will be noticed that the area of outcrop of these sandy strata narrows southward from the Fault. Throughout the area southeastward and eastward of the mines these sandstones do not show themselves, except near the Jack Mines, and they probably do not form any large proportion of the group between the Mines and Village Creek. And this area, free of such sandstones, or containing but a few feet thickness of them, probably extends still further east to the boundary of the property, and northward to the Fault as far west as the eastern part of the Jack Diggings.

Area characterized by Sandy condition of Lead-bearing Group narrows southward from the Fault C-D.

In the Copper Mine neighborhood there are some of these sandstones extending a few feet upward from the contact with the Lower Sandstones, and perhaps a few isolated thin strata higher up in the group. They do not form a large proportion of the group, and seem to disappear going southward, for at the brook in Plot S. 7, W. 8, where the lowest strata in the

Little Sandstone in Lead-bearing Group in Copper Mine neighborhood.

group are exposed in contact with the Lower Sandstones, none of these higher sandstones appear.

POVERTY OF LEAD-BEARING GROUP WHERE ITS STRATA ARE SANDY.

No considerable amount of lead ore has been found where the strata of the group have this sandy character. There is a report, I can not say how well authenticated, that one or more pieces have been picked up near Little Rock Creek, where these strata outcrop. A little has been mined in Plot N. 4, E. 3, where the strata are becoming sandy, going northwest from the Seed Tick Diggings. The area of outcrop of the groups where characterized by large proportion of sand, is as large as where it is free from sand, and the natural exposures of the former are more numerous and extended than of the latter, and while lead ore has been obtained at short intervals all along the natural exposure of the latter, and forty per centum (see below) of the area of it explored by mines has yielded lead, none, with the trifling exceptions above noted, has been taken from the group where its strata are made up largely of sand, ochre and feldspar grains, and my own careful examination of exposures failed to discover any.

It is improbable, therefore, that the areas where the group has these characteristics contain any valuable proportions of ore, and such areas are to be classed with those where the Lower Sandstones and porphyry outcrop, as portions of the tract which do not present chances of finding lead ore sufficient to warrant any considerable expenditure for exploration.

CHARACTER OF THE ORE AND ASSOCIATED METALS.

The lead ore consists of galena or sulphide of lead, associated in places with sulphides of iron or iron pyrites, sulphide of copper and iron or copper pyrites, and sulphides of nickel and cobalt.

METHOD OF OCCURRENCE OF THE ORE.

The ore deposits are mostly imbedded in the strata, and in this respect differ from deposits occupying fissures or veins cutting across the strata. The ore is disseminated through the rock of the stratum in which it exists, or in other words is one of the constituents of the stratum; and in this respect is to be classed with the ores of the St. Joseph and Des Loge Mines of the adjoining County of St. Francis, and distinguished from the greater part of the known important deposits of Missouri, Iowa, Illinois, and Wisconsin, which are branches, strings and larger masses of galena, occupying, in company frequently with clay and ochres, caves and channels in limestone or in masses of loose chert remaining from decomposed cherty limestone strata.*

Character and Extent of Ore-bearing Areas.

The ore does not occupy continuously a very large area of a stratum, but occurs in patches of the stratum which extend lengthwise and widthwise in the plane of the length and width of the strata, and are comparatively thin in direction of the thickness of the strata; or in other words, the patches are lenticular shaped and lie with their broad surfaces in the planes of stratification.

The ore does, however, sometimes follow joints or cleavage cracks, and occasionally where one of these joints has been enlarged by action of water, ore is found in considerable quantities associated with earthy materials in the cavity. At the Golden Vein there must have been, judging from reports, a very large cavity of this kind containing a great mass of ore.†

Character and Condition of Ore in Earth or Loose Materials.

Where the ore-patches come to the surface, and the strata in which they are imbedded are decomposed to the condition of earth, the sulphide of lead or galena is more or less decomposed also, and changed to carbonate of lead, called "dry-bone" by the miners. The galena and carbonate of lead (cerussite) when found in the earth are called "clay mineral" by the miners, and the earthy mass containing them is known as "*bonne terre*."

The two Beds from which most of the Ore has been taken.

The greater part of the ore thus far mined has been taken from the two portions of the vertical section of the Lead-bearing Group which I have already designated as the Bluff Bed and Jack Bed.

Position of the Bluff Bed.

Mines in the Bluff Bed.

The Bluff Bed is in the lower subgroup (oolitic, silicious limestones), and its floor is from 15 to 32 feet above the Lower Sandstones (see Sections 1 to 7, 10 and 11). It is the ore-bed of the Bluff and Prairie Diggings, and all the excavations west and south of them, including the Golden Vein, Helarker, Castor and Wild Cat Diggings, and others not named, and of the Copper Mines.

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* The Golden Vein deposit was similar to some of these (see below).

† I cannot speak more certainly of this deposit, because the excavation was filled with water during the survey.

CHARACTER OF THE BLUFF BED.

The bed generally contains some strata of the hard silicious oolite above described, most commonly at, or just above or below, the roof of the mines, but also in other parts of the Section, and the rock generally has a sandy appearance from the oolitic silica. There is more or less of crystalline calc spar scattered through it, at times, and the green chloritic mineral above mentioned gives to the rock a color of mixed green and gray; at times this chlorite prevails and is mixed with calc spar to form a mottled green and white rock, called by the miners, "calico rock."

IRON AND COPPER PYRITES AND NICKEL ORE IN BLUFF BED.

At the Bluff Diggings the proportion of other sulphurets than galena (iron pyrites, copper pyrites, &c.) in the bed is small, but at the Copper Mines it is large, and very considerable amounts of sulphurets of copper and nickel and cobalt have been mined there. I am informed that at the Castor Diggings, also, these sulphurets were found in large proportions, and were mined for the copper, nickel, and cobalt in them. At present there is no exposure of any considerable amount of nickel and cobalt and copper sulphurets, but more or less of them occur scattered through the ore generally, and the metals are found in the slags and matte produced in smelting it.*

THICKNESS OF THE BLUFF BED.

The bed varies in thickness; in the Sections I have assigned to it a thickness of 7 feet. The underground excavations made on the bed are generally from 5 to 7 feet thick, but in parts of the Bluff Diggings they are 10 and 11 feet thick, and there is a tendency of the ore to extend into higher strata going north towards the Seed Tick Diggings. In the westerly parts of the Copper Mines, the excavation is 10 feet high in places, but it is hard to say whether this is caused by thickening of strata or extension of ore into higher strata.

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* The whole subject of association of these sulphurets with the galena in the ores of the tract is one requiring a careful chemical and mineralogical investigation, which I have not had opportunity to make. It could best be carried on together with smelting the ores of different areas by themselves, and weighing and analyzing the dressed mineral and slags and matte.

PROPORTION OF RICH AND BARREN AREAS IN BLUFF BED.

The proportion of rich area of the bed, or the proportion of rich patches to barren intervals, varies through a wide range. Judging from all the data attainable by survey and examination of all the excavations heretofore made, about 40 per centum of the area over which the excavations are distributed has yielded mineral in quantities deemed sufficient to encourage working, or in other words, the ore-patches considered workable have composed 40 per centum of the whole area explored, and the portion considered barren, 60 per centum of the whole area explored. Much poorer rock can be worked than was regarded rich enough to be mined formerly, but on the other hand the decomposed condition of the beds at their outcrop, has rendered portions of them workable which could hardly be mined away from the outcrop.

PROPORTION OF GALENA IN THE RICH PATCHES OF BLUFF BED.

The proportion of galena within the workable areas or patches, also varies very widely. I have had opportunity to test one area by actual survey of the excavation, together with the returns of product from the books at your office. It was in the so-called "Swinney's New Drift," in Squares 4 and 5, Plot N. 2, E. 4, in the Bluff Diggings. The area excavated was 1796 square feet. The product was 310 car-loads of ore, weighing about 5,604.38 lbs. each, making in all 1,675,977.8 lbs. The ore yielded in the dressing works 23.21 per centum, or 389,009 lbs. (net), of mineral (galena, with some impurities). The mineral yielded by smelting about 65 per centum of lead, or 252,856 lbs., which is 15.09 per centum of the ore. The yield per square foot of the area of the drift was:—

PROPORTION OF GALENA AND ORE IN THE TEST CASE OF SWINNEY'S DRIFT.

YIELD PER SQUARE FOOT IN SWINNEY'S DRIFT.

Of ore,	933.17 lbs., or 0.4666 tons;
Of dressed mineral,	216.6 lbs., or 0.1083 tons;
Of lead,	140.8 lbs., or 0.0704 tons.

THICKNESS OF ORE AND GALENA IN SWINNEY'S DRIFT.

The excavation was 7.15 feet high, and comprised 12,846.4 cubic feet. The ore occupied 8,495.3 cubic feet, and had an average thickness of 4.73 feet. The galena obtained occupied 834.78 cubic feet, and had an aggregate thickness of 0.465 foot, or 5.58 inches.

PROPORTION OF LEAD TO WHOLE MASS MOVED IN SWINNEY'S DRIFT

The whole mass of material excavated weighed about 2,411,482 lbs., or 1,205.74 tons (of 2,000 lbs.), and the lead obtained constituted 0.10485, or a little less than 10½ per centum by weight of the whole mass of material moved. The lead obtained was not weighed, but was estimated according to the average yield of mineral at the works. The lead actually existing in the mineral was about 20 per centum greater than the product obtained, owing to loss in smelting; and the amount of mineral in the ore was some 12 per centum more than the amount obtained, owing to loss in dressing. The amounts and proportions of lead actually existing in the bed is about one-third greater than of the product obtained; but as both dressing and smelting are fully as well done as is usual in this country, the product obtained may be taken as the available quantity existing in the ore of the drift.

YIELD OF THE WHOLE AREA OF THE BLUFF BED THUS FAR EXCAVATED.

PRODUCT PER SQUARE FOOT OF BLUFF BED.

The ore-patch worked in this drift was much richer than the average. Taking as a basis for estimate the whole area of the Bluff Bed thus far excavated which I ascertained as definitely as practicable by survey, and the whole amount of lead thus far obtained from it as nearly as can be learned (see Appendix B), the product per square foot of excavation has been 35.427 lbs. of lead, or 1,543,200 lbs. per acre. If the lead formed 65 per centum of the dressed mineral or galena, the latter amounted to 54.5 lbs. to square foot, and its average aggregate thickness was 0.117 foot, or 1.4 inches. As a large proportion of the mining has been done at the outcrop where the rock was partially decomposed and therefore easily dressed and smelted, it is probable that as large a proportion of the lead was obtained as will now be extracted from the solid rock, and 54.5 lbs. of galena to the square foot, or a thickness of 0.117 foot may be taken as the average probable thickness of available galena to be expected from the ore-patches of the bed, so long as its character remains essentially unchanged.

THE JACK BED, ITS SITUATION.

The Jack Bed is situated at the base of the upper subgroup of the Lead-bearing Group. Its floor is 31 feet above the floor of the Bluff Bed, and from 46 to 63 feet above the top of the Lower Sandstones. It is the ore bed of the Jack

Diggings and Rattlesnake Diggings, and is the "Black Lead" of the Seed Tick and Bluff Diggings.

Character of the Jack Bed.

It is distinguishable from the Bluff Bed by absence of oolitic silica, and by presence of clay in the rock which frequently forms slate varying in thickness from a mere slatey "parting" to two feet or more.

Jack Bed at the Jack Diggings.

Jack Bed at the Rattlesnake and Bluff and Seed Tick Diggings.

Thickness of the Jack Bed.

Extent of excavations on Jack Bed at Jack Diggings.

Product of Jack Bed at Jack Diggings.

At the Jack Diggings the bed consists generally of layers of slate and a coarsely crystalline gray limestone, which passes into calc spar almost imperceptibly. The clay in it has a tendency to form slatey partings and gives the limestones a partially laminated structure. The galena deposits show the tendency to a laminated structure, and frequently take the form of sheets of mineral in the limestone. A small proportion of the galena is found in the slate. At the Rattlesnake Diggings, and in the "Black Lead" at the Seed Tick and Bluff Diggings, there is very little slate in the lower ten feet of the subgroup which includes this bed, but the rock is blue, or where weathered, dark gray. In the Seed Tick and Bluff Diggings, the rock immediately under the Jack Bed is white, but in parts of the Jack Diggings and at the Rattlesnake Diggings, it is dark colored. The thickness of the bed varies like that of the Bluff Bed. Over the greater part of the area of the workings the ore has been limited to a thickness of about 7 feet or less, but in places ore is found, and has been taken out, to a height of 11 feet above the bottom of the bed. Where the bed was richest I am informed that the ore occupied the greater part of about 7 feet thickness, and since that was excavated, 3 or 4 feet more of the rock has been broken down from above the roof, for the ore in it, over a considerable area. A little scattered galena is found in films, in joints and in small bunches and nests, to a height of 17 feet above the bottom of the bed in places, but only over a small area. The excavations of the Jack Bed at the Jack Diggings and neighborhood, including the Hardscrabble Diggings, extend over an area of about 306,788 square feet, or 7.043 acres, and as far as can be ascertained from the accounts kept with miners, statement of the foreman of miners, &c, there has been obtained from this area 18,259,156

Thickness of Galena in Jack Bed at Jack Diggings.

Product of Jack Bed in the Main Mine at Jack Diggings.

lbs. of lead, making a yield of lead per square foot of 59.517 lbs., and per acre of 2,592,561 lbs. By the processes employed probably the galena yielded not more than 60 per centum of lead, making the available galena 99.195 lbs. per square foot, equal to a thickness of 0.213 foot or 2.55 inches. The main mine at the Jack Diggings has an extent of about 159,862.5 square feet, or 3.67 acres. The greater part of the product has come from the main mine, probably three quarters of it, or 13,694,367 lbs. from an area of 159,862.5 square feet, which would make product in lead per square foot 85.6634 lbs., and per square acre 3,731,498 lbs. Estimating that by the smelting processes employed, 60 per centum of lead was obtained from the galena, the available galena per square foot would be 142.772 lbs., which would make the average thickness of available galena in the main mine of Jack Diggings 0.3064 foot or 3.6768 inches. This last estimate is necessarily a rough one. The estimate of thickness over the whole area of Jack Diggings is correct within a comparatively small margin for probable error. I have no means of estimating the amount of galena in this bed at the so-called Black Lead in the Bluff Diggings and the Seed Tick Diggings.

Other Sulphides than Galena in Jack Bed.

There is more of sulphide of iron in this bed as a whole than in the Bluff Bed. It sometimes occupies a large part of the thickness of the Black Lead in the Bluff Diggings. Some sulphide of copper and iron or copper pyrites is visible at times.*

Lead Ore in Strata between Jack and Bluff Beds.

At the Seed Tick Diggings lead in considerable quantities has been taken out between the Jack and Bluff beds where it exists in cleavage cracks, and in irregular bunches or vertical "seams." Indeed, the galena scattered through the rock between the two beds is probably sufficient to render the whole mass workable, at least over a small area. The tendency already mentioned of the ore to extend upwards from the Bluff Bed into overlying strata, continues northward to the Seed Tick Diggings, and the Bluff Bed seems to be rich to a height of 14 feet above the floor at one place there.

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* Mr. Setz, foreman of the smelting-works, informs me that the proportions of nickel, cobalt and copper obtained from the ores of this bed at the Jack Diggings do not differ materially from those obtained from the Bluff Bed at the Bluff Diggings, but the ore from the Black Lead (which is the Jack Bed) at the Bluff Diggings is much richer in these minerals, while the ore of the Copper Mine (Bluff Bed) is the richest now obtained. But, as I have said before, the proportion and method of occurrence of the other sulphides associated with galena can only be learned by careful chemical and mineralogical investigation.

ORE ELSEWHERE IN THE GROUP OUTSIDE OF THE JACK AND BLUFF BEDS.

Except at the Seed Tick Diggings, no workable ore has been found in considerable quantities outside of the Bluff and Jack Beds, and a few feet of strata overlying each. A little has been found scattered through the limestone to a height of 17 feet above the floor of the Jack Bed, and some sulphides of iron, copper, and nickel and cobalt, with perhaps some galena, have been found in strata lower than the bottom of the Bluff Bed at the Copper Mines, and perhaps at the Castor Diggings.

AREA OF ALL EXCAVATIONS IN ORE-BEDS ON THE TRACT.

PRODUCT OF ALL MINES ON THIS TRACT UP TO JAN. 1, 1877.

PRODUCT PER SQUARE FOOT

AVERAGE THICKNESS OF GALENA.

The area of all the excavations made in extracting lead ore on the tract amounts to about 2,939,000 square feet, or 67.47 acres. The whole product of this area, as near as can be estimated from all the data I have been able to obtain (see Appendix B), is 110,571,437 lbs., or 55,285.72 tons. This is at the average rate of 37.622 lbs. per square foot, and 1,638,825 lbs. per acre, and about three per centum, by weight, of the material to be moved in obtaining a like amount from a like area in solid rock. As the ore from which this has been taken was largely freed from rock by natural process, it may be safe to estimate that the lead obtained will represent 65 per centum of the galena which would be available in similar deposits in the solid rock where the ore is principally to be obtained hereafter, making the available galena to the square foot 57.88 lbs., and its average thickness 0.1242 foot, or 1.49 inches.

PRESENT COST OF MINING.

GALENA OF THE AVERAGE THICKNESS CAN BE WORKED AT LESS THAN PRESENT COST OF MINING.

In the case of the Swinney Drift above mentioned, the price paid for mining and delivering the ore at the tramway amounted to two cents per pound of lead, and this at the above estimated rate of average product of the area heretofore worked would amount to 75.24, or essentially 75¼ cents per square foot, which is considerably more than the necessary cost of mining (see below, page 42). I conclude, therefore, that an area with the same average thickness of ore as that which has been heretofore worked over, partly in earth, partly in rock, could be mined in solid rock underground at a cost considerably less than the present price paid for mining. The cost of mining per pound of lead could be reduced by leaving out the poorer part of the patches, but it can in all probability be made profitable to mine all the ore-patches of the average thickness of the patches which have already been mined.

Proportion of Rich and Barren areas.

The area heretofore excavated is 2,939,000 square feet, or 67.47 acres. The excavations have been confined principally to the ore-bearing patches of the bed. I estimate that the area exhausted is about 7,347,500 square feet, or 168.675 acres, or two and a half times the area of the rich patches; or in other words, the patches which have been found workable form forty per centum of the area over which they are distributed.

Extent of area of Lead-bearing Group.

The area occupied by the Lead-bearing Group, where its strata are not so sandy as to preclude the probability of rich ore-patches, in the eastern part of the estate, is about 110,230,696 square feet, or 2530.55 acres, and in the Copper Mine neighborhood, about 23,745,200 square feet, or 545.11 acres, making a total in both regions of 133,975,896 square feet, or 3,075.66 acres.

Relative Probable Richness of the area heretofore worked and the remaining Rich area.

The position of this area explored by mines in the eastern part of the estate is at and near where the Jack and Bluff Beds outcrop, and includes a very large proportion of the whole outcrop of the beds within the area. There is no excavation more than 1000 feet from the outcrop of the bed, but in going nearly 1000 feet from the outcrop the proportion of rich patches does not decrease, nor does the richness of the patches themselves, and we know of no reason why they should do so; or in other words, we know of no conditions favorable to the occurrence of galena in the beds which exist near the outcrop of these beds that do not exist over the whole area east of the outcrop and south of the Great Fault*

Ore deposits probably richer near Faults and Fractures of Strata.

* It is probable that the ore-deposits are richest, other things being equal, where there are the most fractures of the strata; and it is probable, also, that the fractures decrease going southeastward from the mines on the eastern part of the estate, but the decrease can hardly be rapid enough to affect this general conclusion, especially as none of the patches which may exist near the Great Fault (C-D) have yet been opened.

(C–D on Map and Diagram No. 1). Moreover, the portion already explored extends about one-third of the way around the area, farther than the distance across it in a straight line in any direction. On these grounds, I estimate that the chances are even for a proportion of lead ore over the whole of this area as large as that found in the part thus far explored.

The same general conclusion applies to the Copper Mine neighborhood, except that there the exposed portions do not form so large a proportion of the whole outcrop, probably because a much larger part of the outcrop is hidden by chert and other loose materials here than in the eastern part of the tract.

PROPORTION OF RICH AREA EXHAUSTED TO RICH AREA REMAINING TO BE WORKED.

The extent of the two areas is, as above stated, 133,975,896 square feet, and of the portion exhausted 7,347,500 square feet. There remains, therefore, an area of 126,628,396 square feet, or 2,907 acres, which promises to yield a product proportionately as large as that heretofore obtained. It is 17.2342 times as large as the exhausted area, and promises a product 17.2342 times as large as that heretofore obtained. To put it in another form, there are even chances that forty per centum of the remainder of the area, or 50,651,358 square feet, will yield 37.622 lbs. of lead to the square foot, or 1,905,605,391 lbs. in all, at a necessary mining cost less than the price at present paid for mining. A smaller amount can be obtained at a still less cost by working only the richer patches.

PROBABLE FUTURE PRODUCT.

PROBABLE EXISTENCE OF RICH AREAS OTHER THAN THOSE INDICATED IN THE ABOVE ESTIMATE.

I have confined estimates to those portions of the tract named because there are no means of making estimates for any other portions. But there is a large area of the Lead-bearing Group north of the Great Fault (C–D) and east of where the strata are known to be so sandy as to preclude probability of finding lead ore, where there are chances of rich deposits which warrant some small expenditures for exploration.

ACCESSIBILITY OF THE ORES.

OUTCROP AND POSITION OF THE ORE-BEDS RELATIVELY TO THE SURFACE.

Over the greater part of the areas for which the above estimates are made the ore-beds are very accessible. For 62.28 per centum of the areas there are no strata, or if any, a small thickness of strata, above the Lead-bearing Group.

On about 31.14 per centum the Lead-bearing Group is overlaid by a greater or less thickness of the Massive Magnesian Limestone Group, and on 6.58 per centum it is overlaid by all the Massive Magnesian Limestone Group and a part of the Cherty Group.

The exact boundary of the outcrop of the different groups over the large area it is impossible to determine without very detailed explorations by excavation and drilling, but the coloring on the Map together with the contour lines show it approximately, and I will here add some details in regard to exposure and position of strata.

POSITION OF ORE-BEDS S. AND S.W. OF THE BLUFF DIGGINGS.

The series of uplifts by faults and steep dips which bring up the sandstones southwest of the Bluff Diggings continue southeasterly across the West Branch of Village Creek, and to and across the Main Creek itself. On the southwest side of these uplits the higher parts of the Lead-bearing Group are wanting in the area southwest of the West Branch of Village Creek, and to some distance not definitely determined southeast of it. The natural exposures are all of rocks below the bottom of the Jack Bed, and undoubtedly the greater part of the outcrop is of these lower rocks. There is, however, at least one isolated patch of the Jack Bed remaining, for in Plot S. 3, E. 6 (see Map) some pits show shales of the upper sub-group in the loose material lying upon the outcrop of rock, and the Jack Bed probably remains there. The Bluff Bed remains over a large part of this area, and some excavation has been done in it in Plot S. 3, E. 8, not far from an old stack or chimney. The colored contour lines show approximately the position of this bed. It is not deeply buried at any part of this area. The strata descend going southeast, and the exposures in the bed of the brook which flows southward to Village Creek east of the great porphyry exposure are all of strata of the upper sub-group, and consequently both the Jack and Bluff Beds remain there, the former with but little overlying rock: and

POSITION OF BEDS NEAR VILLAGE CREEK S.W. OF UPLIFTS.

from the uplift in Plots S. 6, E. 10, and S. 6, E. 11, Village Creek flows southwesterly over rocks of the upper sub-group to the corner of the property and beyond to a point in Plot

S. 9, E. 6, where another uplift brings up the rocks of the lower sub-group to the surface.

Position of Ore-beds in the trough to which the Bluff and Seed Tick Diggings belong.

The colored contour lines on the General Map show that the Bluff Diggings and the Seed Tick Diggings are on the two sides (S. W. and N. E.) of the raised northwestern end of a trough which continues southeastward to and across Village Creek. Over nearly all of this trough both the Bluff and Jack Beds remain, and at the deepest parts of it considerable areas of the lower parts of the Massive Magnesian Limestone Group remain. These outcrop and are exposed in the southern side of the West Branch of Village Creek, in Plots S. 1 and 2, E. 8, and S. 1 and 2, E. 9, and they form the bed of the Main Village Creek from the crossing of the fault or uplift above mentioned (downthrow on the northeast side) up to some point in Plot S. 4, E. 11; and a brook coming in from the northwest flows over strata of the same group in Plot S. 4, E. 10. Higher up Village Creek the Lead-bearing Group appears, and galena is exposed in strata of the upper sub-group (probably of the Jack Bed) in Plots S. 3, E. 12, and S. 4, E. 12 (see General Map). Above this point the Main Creek flows over strata of the upper part of the Lead-bearing Group or of the lower part of the Massive Magnesian Limestone Group, all the way from the Great Fault (C–D). The sandstone of the Massive Magnesian Limestone Group, which is shown on the Map near the Great Fault, when in place is but about 27.27 feet above the top of the Lead-bearing Group, and 42.27 feet above the top of the Jack Bed. On all of the area south of the fault and east of Village Creek to the boundary line, some strata of the Massive Magnesian Limestone exist, and on a part of it the whole series of this group and some strata of the Cherty Group, as shown on the Map.

Position of Ore-beds in Village Creek above the last-described trough.

Position of Ore-beds indicated by exposures in Hardscrabble Branch.

The exposures on the Hardscrabble Diggings Branch and the brooks which flow into it are all of the upper sub-group of the Lead-bearing Group, and it flows over strata not far above or below the Jack Bed throughout its entire length, except perhaps the lowest exposures near its mouth, which may be the lowest strata of the Massive Magnesian Limestone

Position of Beds indicated by exposures in Rattlesnake Diggings.

Group. The exposures on the Rattlesnake Diggings Branch are also of the upper part of the Lead-bearing Group, except right at its head where are loose pieces of the sandstone of the Massive Magnesian Limestone Group. The Main Western Branch of Village Creek heads also among loose pieces of the sandstone of the Massive Magnesian Limestone Group, but all of the exposures excepting these loose pieces are of the upper part of the Lead-bearing Group down to Plots S. 1 and 2, E. 9, and S. 1 and 2, E. 8, where are the exposures of the lower part of the Massive Magnesian Limestone Group above mentioned.

The Hardscrabble, Rattlesnake, and Main West Branches all flow down eastern slope of the trough in which the Bluff and Seed Tick Diggings lie. They head north of this trough, and the Rattlesnake Diggings are outside of it.

Outcrop of Lead-bearing Group between Jack and Rattlesnake Diggings, and position of the group N. of this outcrop.

Exposures of Lead-bearing Group in Mine Creek.

Hardscrabble Branch and Rattlesnake Branch and Main West Branch all flow down the northeastern slope of the trough to which the Bluff and Seed Tick Diggings belong, but they head a little way north of its northeasterly rim. The Rattlesnake Diggings are also north of this rim, and the strata there dip in northeasterly directions. The outcrop of the Lead-bearing Group extends from these diggings to the Jack Diggings, but the northeasterly dip soon carries its strata under rocks of the Massive Magnesian Limestone Group, and these are in turn overlaid by strata of the Cherty Group where the land rises high near the fault (C–D). In Plot N. 7, E. 9, there is an exposure in the bed and bank of Mine Creek of strata of the upper part of the Lead-bearing Group, and higher up on the hill are the sandstones (loose) of the Massive Magnesian Limestone Group.

Position of Ore-beds west of Bluff Diggings.

All about the Golden Vein, and Helarker, and Castor, and Wild Cat Diggings, there are none of the upper sub-group of the Lead-bearing Group, and consequently the Jack Bed is absent; except in Plots N. 1, E. 1, and S. 1, E. 1, where I think there is a small area of outcrop of the upper sub-group.

Position of Beds in the Copper Mine neighborhood.

In the Copper Mine neighborhood, there are no exposures of the Lead-bearing Group or overlying groups in place except at the mines and in the bed of the brook in Plots S. 7, W. 8, and S. 7, W. 9. The latter exposures are of the lower sub-group. The strata at the mine dip toward high hills, and are at short distance from the outcrop overlaid by the Massive

Magnesian Limestone Group and also the Cherty Group, and the chert remaining from strata of the latter group which have been disintegrated rest on and conceal all the outcrop of the Massive Magnesian Limestone and the greater part of the outcrop of the Lead-bearing Group.

EXPLORATION.

Over all the large area where the Lead-bearing Group outcrops or is overlaid by only a few feet of the next higher group, exploration will be comparatively inexpensive, for the whole thickness of the Lead-bearing Group averages but about 76 feet, and the floor of the Jack Bed is but about 22 feet, and of the Bluff Bed but about 53 feet, below the top of it, so that the deepest drill holes to be sunk where these strata outcrop need not be 60 feet* in depth, except occasionally one might be sunk 76 to 80 feet to the Lower Sandstone to see if any ore exists below the Bluff Bed. It may also be sometimes judicious to sink to the Lower Sandstone to find more certainly to what part of the series the beds explored belong.

The descriptions of the sub-groups and beds above given, together with the Sections, are definite enough, I hope, to enable one having charge of the explorations to indentify the strata reached by the drill or by shaft, especially in connection with the Map; but I will call attention again to some easily recognized characteristics of different portions of the group and of the Lower Sandstone. The latter may almost always be readily recognized. Its material is almost pure silica, colored sometimes with oxides of iron, but these form but a small proportion of the mass; the uppermost strata show a few scattered grains of feldspar; and right at the top, or at the bottom of the next higher group there is frequently a layer of oolitic sandstone, commonly laminated, and often colored green or black or brown but sometimes white.

Easily recognized characteristics of the Lower Sandstone.

Sandstones of the Lead-bearing Group almost always have feldspar grains or ochre or both, and sometimes chloritic grains mixed in large proportions with the silica, and frequently contain oolitic silica, and pass into limey silicious oolite. In some

Easily recognized characteristics of Sandstones of Lead-bearing Group.

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* The dips are generally so slight as to add very little to the vertical distance across the strata.

cases the grains of feldspar, &c., are so coarse as to make a fine conglomerate or breccia. In rare instances the silica is nearly free from other ingredients, forming a true sandstone.

CHARACTERISTICS OF LOWER SUB-GROUP OF THE LEAD-BEARING GROUP.

The limestones of the lower sub-group are readily recognized by their white or light gray colors with green surfaces and streaks, their oolitic grains and their hardness. They pass at times into a limey quartzite. Sometimes a chloritic oolitic layer occurs and may be mistaken for slate, but can be easily distinguished from the latter by its grittiness.

CHARACTERISTICS OF THE UPPER SUB-GROUP.

The upper sub-group is characterized as a whole by its bluish and dark stone-gray colors weathering to dark drab, though near the top of the series its strata are light gray, frequently with greenish surfaces and blotches of yellow: by the proportion of clay which shows itself in tendency to thin bedding, in slatey partings and in streaks and strata of slate, and in clayey earth where the strata have been decomposed, and by absence of oolitic silica. The dark color and perhaps the slatey streaks of the sub-group sometimes extend some feet into the group below, notably at parts of the Jack Diggings.

SYSTEMATIC EXPLORATION NECESSARY.

Heretofore the ore has been dug at and near the outcrop (where the strata were more or less decomposed and earthy and overlaid by earth) only, or where the strata are still undecomposed but overlaid by only a few feet of rock.

The rich patches have been reached by pits sunk through earth, or by shafts sunk through earth and a few feet of rock; but a large part of the outcrop has now been worked over and the rich patches found at the outcrop are becoming exhausted, and those to be opened hereafter lie mostly under a thicker covering of rock; and a steadily pursued system of exploration will be required to keep in view ahead a sufficient area of ore to insure steady supply and to render it possible to plan and pursue mining to the best advantage. Such exploration will be best carried on by drilling and by running the galleries needed to open and drain and ventilate the rich ore-patches.

EXPLORATIONS TO BEGIN NEAR PRESENT WORKS, AND EXTEND FORWARD FROM THEM.

It will undoubtedly be most economical and advantageous to begin the systematic exploration at the mines where the conditions are best known, and extend it forward from there. The Maps and the geological description above given will afford most of the data required for laying out and carrying forward the exploration; but I will add some further details relating to the different mines and their immediate neighborhood.

EXPLORATION OF THE TROUGH IN WHICH THE BLUFF AND SEED TICK DIGGINGS LIE.

The most necessary exploration for present guidance of mining operations is at the trough in which the Bluff and Seed Tick Diggings lie. The general geological character of the trough has already been given. The Bluff and Seed Tick and a part of the Prairie Diggings lie at the upper northwest end of it.

The greater part of the Bluff and Prairie Diggings are in the Bluff Bed; but at the western part of the Bluff Diggings the Jack Bed has been worked by open cuts (not down on Special Map of the Mine) under the name of the "Black Lead," and underground at the drifts in Squares 63 and 64, Plot N. 2, E. 4, and Squares 6 and 7 of same Plot, and several shafts have been sunk in it (see Special Map of Bluff and Seed Tick Diggings).

The Seed Tick Diggings are both in the Jack Bed (here also called the "Black Lead") and in rock between it and the Bluff Bed. Before the survey was finished one shaft sunk by Wingler and Kling in Square 49, Plot N. 4, E. 3, had struck the strata of the Bluff Bed. Where the Bluff Bed outcrops west of the Seed Tick Diggings it and the strata in which it is imbedded are sandy and contain little or no lead, and this is why the Bluff Bed is not worked there; and over the western part of the Bluff Diggings and southwest of the uplift the Jack Bed is absent, having been carried away.

The Bluff Bed therefore still remains* on all the area where the "Black Lead" has been worked, and both beds exist all over the area of the trough southeast of the excavations of the Bluff and Seed Tick Diggings, except at and near the northeasterly rim (along the south side of porphyry exposure), and going towards Village Creek this rim also becomes overlaid by the whole Lead-bearing Group, including both beds. At the southwesterly rim of the trough the lower strata of the group are brought up abrubtly by uplifts at faults, so that the Lohrey, Scott, and Armstrong Drifts, and the "offset" near the old chimney in S. 2, E. 8, are in the Bluff Bed, and the strata of the upper sub-group, including the Jack Bed, are absent.

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* It has been left because its existence there was unknown before the survey; and indeed, the whole subject of the succession of strata and relative position in the series of the ore-beds was in the dark. There was a general idea that sandstones underlay the limestones, but this was a confused idea, because the Lower Sandstones were not distinguished from sandstones of the Lead-bearing Group.

The rather indefinite record of two drill-holes sunk (in 1870) with diamond drill (see Appendix A, pages 22 to 25, "Hole No. 20, Bluff, Prairie No. 1," and "Hole No. 21, Bluff, Prairie No. 2") in the Seed Tick Diggings, Square 81, Plot N. 4, E. 3, and Square 71, Plot N. 4, E. 4, shows that the rock contains galena down to and below the Bluff Bed. Very possibly the Bluff Bed and all the rock about it could be blasted down in open cut to advantage, and it would be well to determine whether this is the case at once, before any further excavations are carried on there. It would be well to carry a line of drill-holes westward along the southern edge of the "offsets" of the Seed Tick Diggings, and sink one in the shaft in Square 85, Plot N. 4, E. 4.

The drift in Squares 79, 81, 82, 99, 100, Plot N. 4, E. 3, was full of water when the survey was in progress. As there is one and perhaps more faults at and near it, I cannot infer the exact position of the strata there, but the drift was probably excavated for the "Black Lead," and it would be well to see if the Bluff Bed is rich below it. The drift is near the middle line of the trough.

The Lockwood Shaft (Square 67, Plot N. 3, E. 4) is probably but a short distance west of the middle line of the trough, and two faults are reported at and near it. It also was full of water when I was on the ground. Three drill-holes were sunk there (in 1873) with diamond drill (see Appendix A, pages 19 to 21, Holes "No. 1, Lockwood Shaft:" "No. 2, Lockwood Shaft:"

"No. 3, same,") and good mineral reported in one of them at the horizon of the Bluff Bed. It would be well to sink a hole a short distance (say 100 feet) east of the shaft, and to continue the exploration along the eastern part of the Bluff Diggings by drilling in the "offsets" and shafts already sunk on the "Black Lead" (Jack Bed) there, including those at the drifts in Squares 63 and 64, Plot N. 2, E. 4.

DEPTH TO WHICH IT WILL BE NECESSARY TO DRILL IN BLUFF AND SEED TICK DIGGINGS.

In all of the shafts and "offsets" which have been sunk through the "Black Lead" in the Seed Tick and Bluff Diggings it will be necessary to drill but about 30 or 35 feet to be sure of reaching and passing through the Bluff Bed. In the Seed Tick Diggings are a number of excavations extending down to a greater or less depth into the strata between the Jack and Bluff Beds, and here the drill-holes would have to be sunk to a proportionately less depth to reach the Bluff Bed. At other points in the trough it will be necessary to determine where the beds are by observing carefully the character of the rock drilled through. Near the middle of the trough east of the Bluff Diggings several faults are reported, by which the strata shift position abruptly, and then, perhaps, the mistake most likely to be made is to drill not deep enough. This can be provided against by careful observation of the rock, but occasionally it may be best to sink to the Lower Sandstone, partly to see if there may not possibly be valuable ore in the strata below the bottom of the Bluff Bed.

EXPLORATIONS W. AND N.W. OF SEED TICK DIGGINGS.

EXPLORATIONS W. AND S.W. AND S. OF THE BLUFF DIGGINGS.

West and northwest of the Seed Tick Diggings the strata are Lead-bearing for a short distance from the present diggings, but soon become too sandy to warrant exploration. West and southwest and south of the Bluff Diggings the upper sub-group, including the Jack Bed, has been quite generally washed away, and there, perhaps, exploration may as well be continued, as it has been carried on heretofore, by the miners taking their own risks and chances. This applies also to the Helarker, Castor, and Wild Cat Diggings. But there is one small area near the latter, where a part at least of the upper sub-group remains. A pit in Square 75, Plot N. 1, E. 1, shows the gritless shales of the upper sub-group, and in that immediate neighborhood the Bluff Bed lies too deep to be found by the ordinary prospecting of the miners.

EXPLORATIONS OF GOLDEN VEIN DIGGINGS.

The Golden Vein deposit was, according to reports, exceptional in its character. It seemed to occupy a channel excavated by water along the line of a joint and perhaps fault extending N. 28° E. nearly. It is full of water now and I could learn but little of its character. I do not think the chances of finding valuable deposits there warrant the expenditure of much money, but in some very dry season when there is unemployed pumping machinery at hand, and labor is cheap, it may be worth while to examine the channel again. Outside of the channel the exploration of the neighborhood may as well be left, as at present, to the miners.

EXPLORATIONS AT THE JACK DIGGINGS.

The mines at the Jack Diggings proper are in a basin, the position and outline of which are shown plainly by the colored contour lines on the General Map, and on the Special Map of the Underground Mines at these "Diggings."

The strata of the upper sub-group are carried away from the southwestern, western, and northwestern and northern parts of the basin, and the lower sub-group is too sandy in these parts, and perhaps all over the basin, to promise valuable ore deposits in the Bluff Bed there. Moreover the whole area has been pretty well explored by pits and drill-holes. It is not then necessary to explore the area between the outskirts of the Jack Diggings and the outcrop of the sandy strata of the Lead-bearing Group (see Map). Within the area of the Jack Diggings the miners are prospecting and continuing their mines, and in this way will probably reach all the valuable ore-patches there. They are at present prospecting in the narrow space east of the Jack Diggings proper and east of the rim of the basin and between it and the end of the porphyry exposure.

The area of outcrop of the Lead-bearing Group extends along on the northern side of the porphyry exposure to the Rattlesnake Diggings, and the record of some drill-holes (see Appendix A, Holes Nos. 24–29, pages 10 to 13) indicate that the lower part of the Lead-bearing Group becomes free from sand going east, and probably the Bluff Bed becomes free of it in the western part of Plot N. 5, E. 8.

The strata dip in some northerly or northeasterly directions on the north side of the porphyry exposure as far as can be deduced from the few exposures, and the explorations eastward from the Jack or westward from the Rattlesnake Diggings should be far enough north of the porphyry to ensure striking both the Jack and Bluff Beds, and not far enough to render the drilling of unnecessary depth. Williams' drill-holes Nos. 24 to 27, inclusive (see Appendix A, pages 10 to 12), which are laid down on the Special Map of the Jack Diggings with proximate certainty, are not quite far enough north, as they pass through the Jack Bed right at its outcrop where it is broken and disturbed.

MINES AT RATTLESNAKE DIGGINGS, IN JACK BED. EXPLORATIONS ABOUT AND NEAR THESE DIGGINGS.

The ore of the Rattlesnake Diggings is in the Jack Bed, and the bed is exposed and shows a little galena in the brook in Square 22, Plot N. 4, E. 9. Right at the diggings the upper sub-group rests directly on the porphyry, but a little further from the porphyry exposure the Bluff Bed would undoubtedly be found, and it would be well to test it there.

The colored contour line on the General Map extending from the Rattlesnake Diggings northward, together with the arrows indicating dip, will serve to show where the drill-holes can be sunk to and through the beds with as little drilling in overlying strata as practicable. As the dip is northeasterly the overlying strata grow thicker in that direction, and loose pieces of the sandstones of the Massive Magnesian Limestone Group occur at the head of the "Branch" at the south end of the line between N. 5, E. 9, and N. 5, E. 10, and the same sandstones occur at the head of the West Branch of Village Creek in Plot N. 4, E. 11. These sandstones are loose and more or less moved out of place. Where in place they are, as said above, about 27 feet above the top of the Lead-bearing Group, and 42 feet above the top of Jack Bed. Farther down the West Branch of Village Creek, in the last-named plot, are exposures of the upper sub-group of the Lead-bearing Group.

EXPLORATIONS NEAR HARDSCRABBLE DIGGINGS.

About the Hardscrabble Diggings the miners will probably explore the Jack Bed at their own risks and chances,* but it will be well to explore for the Bluff Bed in the southeasterly part of these diggings, beginning at the "offset" now open on the east side of Hardscrabble Branch, in Plot N. 4, E. 7.

EXPLORATIONS IN THE COPPER MINE NEIGHBORHOOD.

The ore-deposits which have been worked up to the present time at the Copper Mine are all of the Bluff Bed. The distinction between the upper and lower sub-groups of the Lead-bearing Group is as marked here as in the eastern part of the tract. Some galena was found at horizon of the bottom of the Jack Bed by drill (see Appendix A, Hole No. 14, page 43).

The strata dip at the main mine at angles higher than usual on the tract, in southeasterly direction, except at the west end of the mine where the strike changes from southwesterly to northwesterly courses, and the dip from southeasterly to southwesterly courses. The land rises fast in the direction from the outcrop of the dip, and consequently the Lead-bearing Group passes under a rapidly-increasing thickness of strata of the higher groups. The Cherty Group occupies the higher parts of the hills, and the Cherty debris has fallen down over the outcrop.

The colored contour lines indicate approximately the trend of the ore-bed northeasterly from the mine, and exploration can be carried on in that direction near the outcrop without drilling to excessive depths.

FORMER EXPLORATIONS OF COPPER MINES WITH DIAMOND DRILL.

I have been enabled to find and identify with the record the eighteen holes sunk with diamond drill about the Copper Mines, in 1873, and have placed them on the Special Map of the Copper Mines and vicinity, and to the record have attached elevations above datum of survey, and notes in regard to the position of the ore-beds in the sections explored by the drill, (see Appendix A, pages 34 to 45), and the results thus identified and brought into connection by survey will be found of material aid in further exploration. Four holes (Nos. 9, 10,

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* I presume that the present systems of mining will be continued for some years at the shallow "diggings" near the outcrop of the ore-beds.

11, 12) southwest of the west end of the main mine seem to indicate that good ore-deposits may exist there; and this is confirmed by experience in the west end of the mine itself. Hole No. 16 discovered the ore-patch which was opened and has been worked at the shaft and drift in Squares 63 and 78, Plot S. 4, W. 11. The record of holes numbered 3, 4, 5, 6, 7 (see Appendix A, pages 35 to 38), warrants further exploration by drilling and shallow excavation in the neighborhood where they were sunk in Plots S. 4, W. 10, and S. 4, W. 11 (see Special Map).

EXPLORATIONS FURTHER FROM THE MINES IN THE COPPER MINE NEIGHBORHOOD.

Away from the immediate neighborhood of the mines in this corner of the tract, the most available opportunity for exploration is near the brook which crosses the line of the property in Plot S. 7, W. 8. It flows over exposures of the Lead-bearing Group within the tract and for a short distance below the boundary line, and then over the contact of this group with the Lower Sandstone Group.

There will be no difficulty in determining the geological horizon there, and in keeping the horizon in explorations up the brook and its branches. The exploration should be made partly by drilling but largely by digging through the loose materials to the outcrops.

EXPLORATIONS FURTHER FROM THE MINES IN THE EASTERN PART OF THE TRACT.

In the eastern part of the tract away from the mines the most available and promising places for exploration are, first at the exposures (see General Map) in West Branch of Village Creek as far down as to the uplifts in Plot S. 2, E. 7, and in the brook that flows into the "Branch" near these uplifts, and in Hardscrabble and Rattlesnake Branches; next in Village Creek, where the uplifts just mentioned cross it (but on the lower side of fault here); where the exposures of galena in the Jack Bed are recorded on the Map in Plots S. 3, E. 12, and S. 4, E. 12; at the exposures in N. 1, E. 13, and N. 2, E. 13, where joints are shown in the General Map, and near the Great Fault on the south side of it in Plot N. 5, E. 13. At the last-named place the local sandstones of the Massive Magnesian Limestone Group may be found in place and loose, in east bank of the creek, and the roof of the Jack Bed is about

42 feet below them where they are in place. A brook heads in S. 4, E. 10, which enters Village Creek near the corner of the property. It flows over the outcrop of the upper part of the Lead-bearing Group, and the exposures present favorable opportunities for exploration; and, I think, near its head, also, where there are no exposures, but where the covering of loose materials is shallow, as proved by the two pits sunk there (see Map), it would be well to drill down to and through the Bluff Bed.

On Mine Creek in Plot N. 7, E. 9, some of the upper strata of the Lead-bearing Group are exposed, and the exposure affords another good opportunity for testing the group near the Great Fault.

If any exploration is done north of the Great Fault the first hole might be sunk a little down stream from the fault that crosses Little Rock Creek in Plot N. 22, E. 2, and then in Big Rock Creek, beginning near the synclinal axis shown on the Map and continuing up the Creek.

MINING.

PRESENT SYSTEM.

The present system of the mining, like the prospecting, has grown up while the work was to be done at or very near the outcrop. It consists essentially in paying to contractors a set price[*] for the mineral product, and permitting the contractor to select one or more lots of 50 feet square each upon which to mine, at any place not already occupied; he taking all the risk and chances of exploration and mining, and conducting both as he sees fit, except cost of taking out water from the drift, which is done by the proprietor in certain cases. The price is undoubtedly based upon experience, and is probably as low as will secure an adequate supply by the system at present, and will fail to secure an adequate supply hereafter as the excavations become deeper. It covers the cost of the mining and exploration, and the cost of maintaining a body of contractors who sub-let the greater part of the work. The

[*] The price is $16.00 per gross thousand (1120 lbs.) of dressed mineral obtained from the ore, less $3.00 per car-load of about 50 cubic feet charged for dressing the ore, when the price in St. Louis for soft Missouri lead is 6½ cents per pound, and more or less than $16.00 proportionately as the price of lead in St. Louis is higher or lower than the standard 6½ cents per lb. (The price has since been advanced to $19.50 instead of $16.00)

system secures the advantage of direct personal interest on the part of the contractor; but the exploration is of a hap-hazard character, without intelligent direction, and a great deal of labor is unnecessarily expended where there is no probability of finding ore, frequently where the ground has been repeatedly tested and found barren, and is so incomplete that a large part of the lead-bearing area opened is worked over two or more times at a cost much greater than would have been necessary to extract all the ore at first.

PRESENT SYSTEM OF MINING NO LONGER ECONOMICAL.

The mining also is done at a great disadvantage. As a rule, each contractor sinks a shaft and opens a drift from it, thus doing his blasting for some time with a short face and "tight sides" all around, the ventilation is imperfect and much time is wasted in waiting for powder smoke to escape; the ore is raised by hand, and in many cases the water also, and much barren rock is raised to the surface which could be left in the drift with a different system of mining.

The general result is that the cost to the contractors is excessive, although the workmen receive low wages.

ILLUSTRATION OF THE PRESENT SYSTEM OF MINING FROM SWINNEY'S DRIFT

In the case of the Swinney Drift already mentioned the amount paid the contractors was $5,060.70 which was two cents per pound of the lead produced. The cost to the contractors was $1,848.47. The excavation consisted of a drift of 1,796 square feet, and a shaft sunk through 13.26 feet of earth and 24.79 feet of rock. The portion of cost assignable to the shaft is probably about $250.00, and about four-fifths of that should be charged to other area than the 1,796 feet under consideration, leaving the cost to the contractor of the ore from the 1,796 square feet $1,598.47, or 89 cents per square foot.

COST BY PRESENT SYSTEM.

GENERAL OUTLINE OF A BETTER SYSTEM OF MINING.

The system of mining can now be changed with large reduction in cost by adopting the ordinary method of opening areas of ore by few shafts and long galleries.* The ore to be carried on underground tramways, and the water drained to a centrally situated shaft where there is a pump and hoisting machine. The shafts would be sunk, and the galleries driven, and the stoping or blasting down of the ore done, by contract, and so also would the "clearing of the mine," that is, the taking away ore from the face where the blasters leave it, and the removal of the small amount of barren rock that could not be left in the drift. The pumping, hoisting up the shaft, timbering, and maintenance of tramways in the mine would probably be done by workmen paid by the day.

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* Usually called "drifts," but this name has been adopted at Mine la Motte for "stoping ground."

NECESSARY COST OF MINING BY THE SYSTEM RECOMMENDED.

I estimate that the work could be done by this system at the following costs per square foot of area mined:—

Blasting, including powder, fuse, and candles, ...	$0.30
Proportionate charge for shafts, galleries, tramway, pumping, hoisting, timbering, exploration,....	.10
"Clearing mine," including all handling of ore and rock after it is blasted down,..........................	.10
Steel, blacksmithing, carrying drills, foreman's salary, and other small incidental expenses,......	.03
Total mining cost per square foot,	$0.53

This estimate is necessarily rough, because the deposits are of an unusual character, and no experience has been acquired yet on the ground in such work, and because the cost would be modified by circumstances more or less contingent; but the margin for probable error is not large, and the general inference that the mining can be done much more cheaply by this than by the present system is certainly correct. I think that by using preparations of nitro-glycerine instead of powder, and drilling by machinery (for which the character of the deposit is unusually well adapted), the cost can be reduced materially below this estimate.

Another consideration to be taken into account is that the galleries serve to explore the areas through which they pass, and show where the rich patches exist.

THE CHANGE OF SYSTEM OF MINING TO BE BEGUN NEAR THE SEED TICK AND BLUFF DIGGINGS.

The change in mining could be begun with the greatest advantage in the trough of the Seed Tick and Bluff Diggings, and not far from the present mines there, by sinking a shaft at some point in the lowest N.W.-S.E. line of the trough to the beds and extending galleries through the areas to be worked.

The colored contour lines on the Special Map of the Bluff and Seed Tick Diggings supply the principal data required for laying out the mine, but some little exploration by drill will be necessary to show just where the lowest line of the trough is, or a gallery might be driven from some one of the present mines or shafts across the trough, and a shaft sunk to the lowest place in the gallery.

APPENDICES ATTACHED TO THIS REPORT.

I attach to this report three appendices:—Appendix A, relating to the explorations made by diamond drill some years since; Appendix B, relating to the history of the production of lead on the Mine la Motte tract; and Appendix C, relating to the maps submitted with this report.

Very respectfully yours,

JAMES E. MILLS,
Consulting Geologist.

ST. LOUIS, MO., *September* 22, 1877.

APPENDIX A.

SYNOPSIS OF APPENDIX A.

RECORD OF EXPLORATIONS MADE IN 1870-'3, BY GEORGE L. WILLIAMS.

[Appendix A contains a record of explorations made with diamond drill, by George L. Williams, beginning in 1870 and ending in 1873. This record occupies forty-five manuscript foolscap pages, and gives the results of boring more than sixty holes. As data for determining the order of the strata, and particularly the position of the Lead-bearing Group, these explorations proved very valuable, and for that reason Mr. Mills has appended the record of them to his report. He has copied the original record, mapped out the strata for each boring, and added his own remarks and deductions, and thus he has preserved in permanent form a large mass of information. This information is, however, only specially interesting to the geologist or to one examining the strata upon the estate. For these purposes, the original report is accessible. A few of Williams' drill-holes will be found on the sheet of Sections, but it has not been thought necessary to print more of them than there appear.]

APPENDIX B.

HISTORY OF PAST PRODUCTION OF MINE LA MOTTE.

It is impracticable to learn with accuracy what these mines have produced, but upon all the data attainable I have made the below-given estimate. To judge of the character of the estimate and the extent and reliability, it is necessary to know the data upon which it is founded, and these I will present briefly.

In 1804, Moses Austin, who was himself engaged in mining lead in Missouri, wrote a letter* which appears among the "American State Papers" (Public Lands, vol. i., p. 188), and which is in effect a report on the condition and extent of the lead mines of Missouri.

He gives the following history of the mines: "Mine a la Motte ...... was discovered by Mr. Renault, about the year 1723 or 1724, who made an exploration, but finding no silver ore he abandoned it. About the year 1723, a man by the name of La Motte opened and wrought the mine after whom it is called.

"....... About the years 1738–40, the Mine a la Motte was considered as public property, and the people in general were allowed to work it. At that time it furnished almost all the lead exported from the Illinois; but soon after the discovery and opening of the Mine a Burton, the Mine a la Motte was in a great measure abandoned, the mineral at the Mine a Burton being much easier melted. The Mine a la Motte is at this time claimed as private property, in consequence of which the inhabitants in general are denied the privilege of working. Therefore the annual quantity of lead is greatly reduced. For the years 1802 and 1803, the quantity of lead made at the Mine a la Motte did not exceed 200,000 lbs. weight, although about thirty men were employed from four to six months in each year."

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* This letter is given in the "Geological Report of Missouri," for 1874.

Upon these statements I have estimated the probable production for eighty years, from the discovery to 1804, at..................	16,000,000 lbs.
(or 200,000 lbs. per year).	

Schoolcraft, in his "View of the Lead Mines of Missouri," published in 1819, says:

"In June 14, 1723, Mine a la Motte was granted to Renault. . . . . This is one of the oldest mines in the Territory, having been discovered A.D., 1720, by the person whose name it bears.

"When Louisiana was first occupied by the United States, Mine a Burton and Mine la Motte were the principal mines wrought. The United States acquired possession of the mines in 1803."

He states that the product of Mine la Motte for the three years ending June 1, 1819, was 2,400,000 lbs., or 800,000 lbs. per year.

The average product of the years 1804 and 1819 would be 500,000 lbs., and I have taken this as the probable annual product from 1804 to 1819, inclusive, making the product for that period,..................	8,000,000 lbs.

Prof. J. D. Whitney, in his "Metallic Wealth of the United States," page 418, says:—

"From 1834 to 1837 Mine la Motte produced on an average 1,035,820 lbs. of lead per annum."[*]

The average of the amount reported by Schoolcraft for 1819, and Whitney for 1834, is 917,910 lbs., and I will take that as the average product from 1820 to 1833, inclusive, making the product for that period,	14,686,560 lbs.
For the period 1834 to 1837, I will take Prof. Whitney's figures,	3,107,460 lbs.

In 1835, Mr. V. R. Allen, the present foreman of the mines, came to Mine la Motte, where I believe he has lived ever since, and to him I am indebted for much information in regard to the subsequent history of the mine.[†] He informs me that up to the year 1838 the carbonate of lead was not known here to be an ore of lead, and under the name of "dry-bone" was rejected as worthless, and a very large quantity of it lay around the pits. In the year 1838, a Prussian of the name of Hagen came to the mines, and entering into partnership with some of the Messrs. Valle, and perhaps others, bought up a large amount of the "dry-bone." They also leased for mining forty lots of forty acres each[‡] and then began to smelt. Soon after they began to produce lead from the "dry-bone" others put up furnaces and mined and smelted the ore. The result was an increased and well sustained production for thirteen years. Janis, who had the largest furnaces, smelted 5,000 pigs, or 350,000 lbs. a year, from 1839 to 1848. There were four other furnaces besides his producing, perhaps, each 3,000 pigs, or 210,000 lbs. yearly, and two ash furnaces producing each about half as much, or 105,000 lbs., making a yearly product from these furnaces of 1,430,000 lbs., which for the period of thirteen years amounted to 18,590,000 lbs. There was besides, from 1840 to 1847, another large furnace in operation, producing probably 4,000 pigs, or 280,000 lbs., yearly, or 1,960,000 lbs. for the seven years,

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[*] Prof. Whitney does not give his authority for the statement.

[†] Much of Mr. Allen's statement has been confirmed, and none of it as here given refuted, by Mr. F. Valle and others. Mr. Allen's accounts agree substantially with other reliable accounts where I have obtained such, but being all from memory they were given and must be taken as only approximately correct.

[‡] The mine had been held, as near as I can learn, under a Spanish grant, by John Baptiste, St. Jemme Bauvais, Francis Valle, John Baptiste Valle, and Joseph Pratte, and the grant was confirmed, it is said, by Congress, in 1827. In 1838, the heirs of the original grantees sold to C. C. Valle, Louis F. Linn, and Everest E. Pratte; and when these parties came into possession they leased the land to parties in forty-acre lots for ten years, and at the expiration of this time renewed for three years longer, or till 1851.

Making the total product for the years 1838 to 1850, inclusive,	20,550,000 lbs.

From 1851 to 1861, Mr. Allen says there was little work done, on account of litigation; and this tallies with a statement of Prof. Whitney's ("Metallic Wealth of the United States," page 419), "In 1852, the number of men employed was not more than twenty, and from all appearances the lead produced could not exceed one or two hundred thousand pounds."

Mr. Allen estimated the product of the whole time at about 20,000 pigs,	1,400,000 lbs.

I will take his estimate for this period.

In 1861, the United States Government destroyed the furnaces, but they were soon rebuilt, and in the years 1861 to 1863, Mr. Allen says that one furnace yielded 26,000 pigs, and the other furnaces yielded twice as much more,

Making in all for the three years a product of 78,000 pigs, or	5,460,000 lbs.

From 1864 to 1868, he thinks the yearly product about the same as in 1868, when it was 1,637,860 lbs.,

Making the product from Jan. 1, 1864 to Jan. 1, 1868,	6,551,440 lbs.

We now come to definite statistics.

Mr. R. Gage, in "Geological Report of Missouri," 1874, states that:—

The product for 1868 was 23.398 pigs of 70 lbs. each,	1.637,860 lbs.
And for 1869, 62,504 pigs of 70 lbs. each,	4.375.280 lbs.

The great increase that year was due to the discovery of the Jack Diggings deposit.

Henry Cobb, in a paper on "The History of Lead-mining in Missouri," published in the same "Geological Report," says:—

"The production in 1870, as determined by the Iron Mountain Railroad Company in transporting it to the St. Louis market was	5,128.000 lbs.

The books in the office show the product:—

For 1871, to have been,	3,602,451.3 lbs.
For 1872,	2,821.933.6 lbs.
For 1873,	2,863,000.77 lbs.
For 1874,	2,463.786.23 lbs.
For 1875,	4.648,090.02 lbs.
For 1876,	5,827,015.04 lbs.

RECAPITULATION.

Estimated	product,	1723 to 1804,		16,000,000	lbs.
Reported	"	1804 to 1819,	inclusive,	8,000,000	lbs.
Estimated	"	1820 to 1833,	"	14,686,560	lbs.
Reported	"	1834 to 1837,	"	3,107,460	lbs.
Estimated	"	1838 to 1850,	"	20,550,000	lbs.
"	"	1851 to 1860,	"	1,400,000	lbs.
"	"	1861 to 1863,	"	5,460,000	lbs.
"	"	1864 to 1867,	"	8,000,000	lbs.
Reported	"	1868 to 1876,	"	33,367,416.96	lbs.
		Total lead product,		110,571,436.96	lbs.

I have no record of the product of nickel, cobalt, and copper. The following statement appears in "Campbell's Gazeteer of Missouri," published in 1875.

"The Mine la Motte Copper Mines, two miles west of Fleming's old smelting furnace, were discovered in December, 1838, by H. N. Tong, Esq., though but little systematic mining was done until 1845, when a practical miner named Marie, from England, purchased an interest in them, and a company was formed who erected a large smelting furnace and began work on an extended scale. For the next three years the net profit of these mines amounted to upwards of $150,000, notwithstanding which, all work on them was abandoned until within the last year, when it was resumed by the La Motte Lead Company, who are working these mines for nickel, large amounts of which are being shipped to Europe for refinement, the mining of Copper having been abandoned."

Mr. Allen informs me that in 1844, "Henry Marie took some of the ores from the Copper Mine to England, and his brother T. Marie returned, and with Janis and Valle mined the ores and smelted them for matte. Marie sent his portion of the matte to England; Janis and Valle sold theirs to Thomas Fleming & Sons. The profit of Janis and Valle for the years 1844 to 1848, was $93,000. From some other information given me by Mr. Allen I infer that some small portion of the matte shipped was from ore taken from the Castor Diggings.

JAMES E. MILLS.

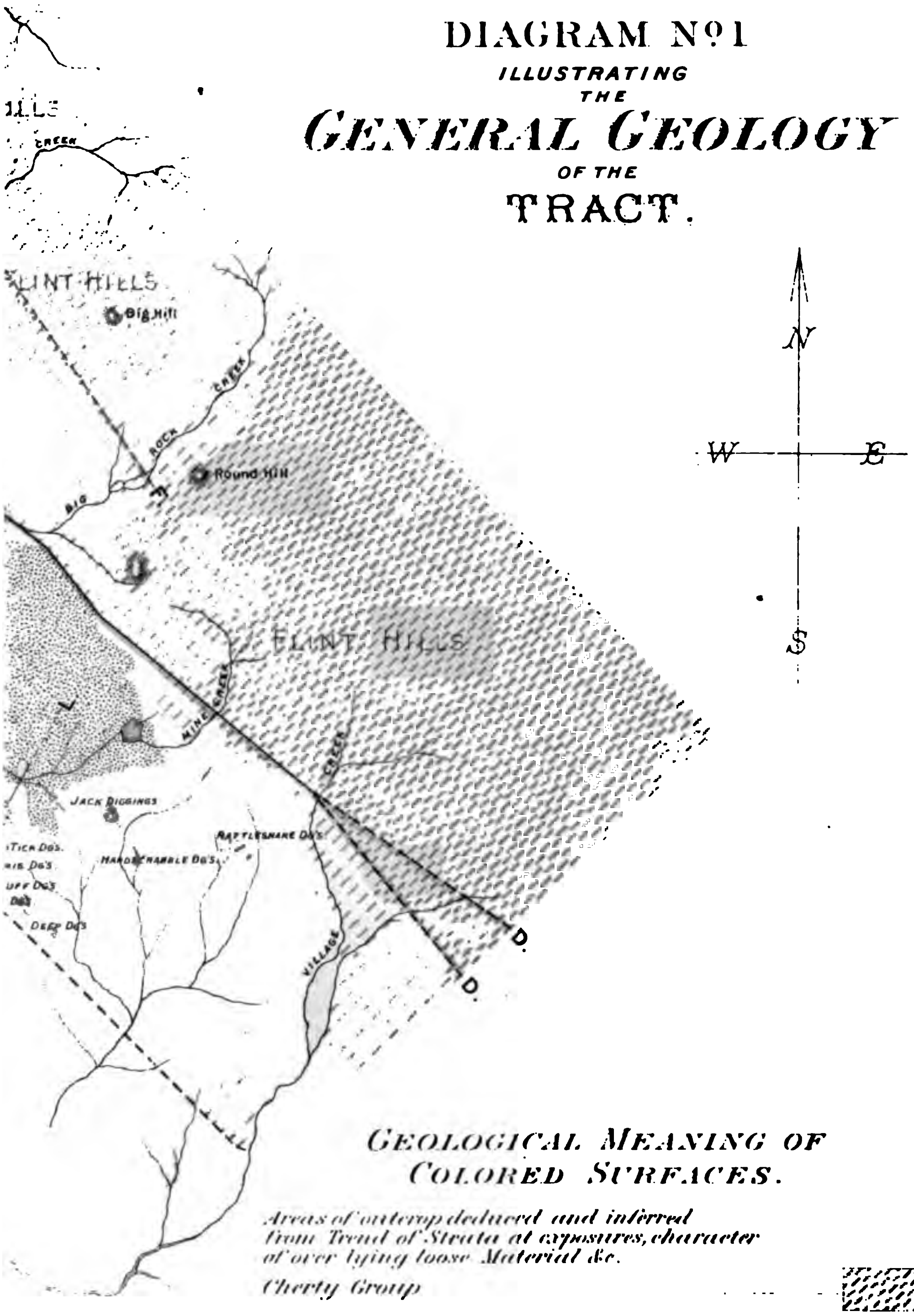
APPENDIX C.

[Appendix C is a list of the various maps presented by Mr. Mills with his report. It includes a General Geological Map of the estate, on a scale of 500 feet to the inch, three Special Maps of Underground Excavations, two cross sections, and over two hundred note-sheets, note-books, &c.

The datum point from which elevations are measured is thus fixed:—

"There is a copper bolt set in a ledge at 3199 feet north of the zero point of the survey, the top of which is 100 feet above datum of elevation of the survey, which last is, according to profile of St. Louis and Iron Mountain R. R., 255 feet above the City Directrix at St. Louis, and according to present information 663.6 feet above sea level."]

DIAGRAM No. 1
ILLUSTRATING
THE
GENERAL GEOLOGY
OF THE
TRACT.



GEOLOGICAL MEANING OF COLORED SURFACES.

Areas of outcrop deduced and inferred from Trend of Strata at exposures, character of over lying loose Material &c.

Cherty Group	▨
Massive Magnesian Limestone Group	▨
Lead bearing Group when consisting principally of Limestones	☐
Lead bearing Group when consisting largely of Sand, Ochre and grains of Feldspar	░
Lower Sandstone Group	☐
Porphyry	☐
Lead Ore exposed naturally or by excavation	■

ICH TO 5,000 FEET

ING REPORT OF
AMES L. MILLS, F. S.
CONSULTING GEOLOGIST

SECTION Nº 1

VERTICAL SECTION OF STRATA FOUND ON THE TRACT.

SCALE 1: 1200 — ONE INCH TO 100 FEET.

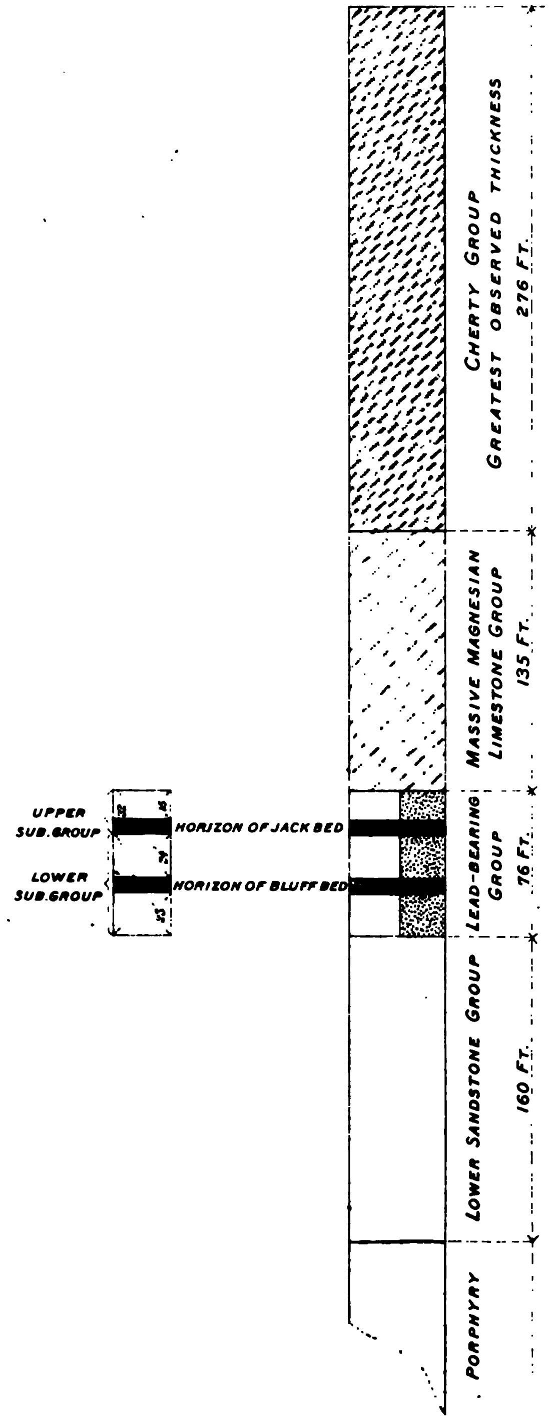


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DIAGRAM

IDEAL SECTION TO ILLUSTRATI
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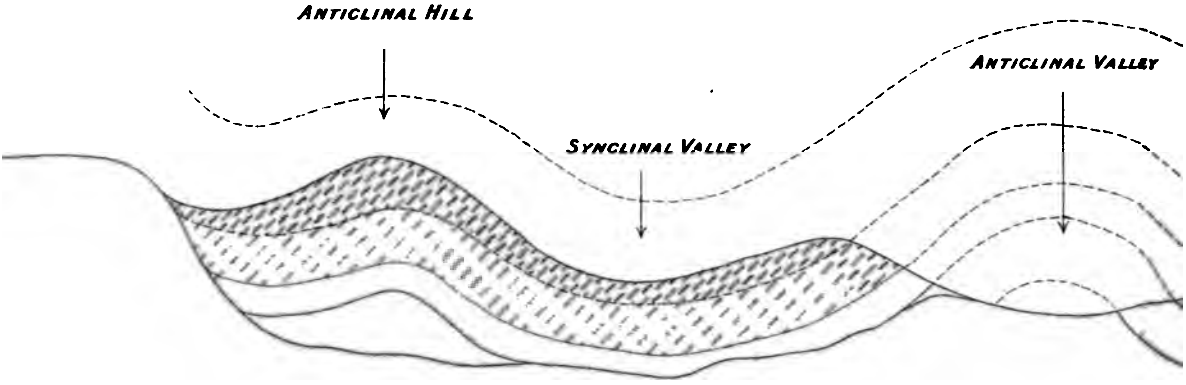
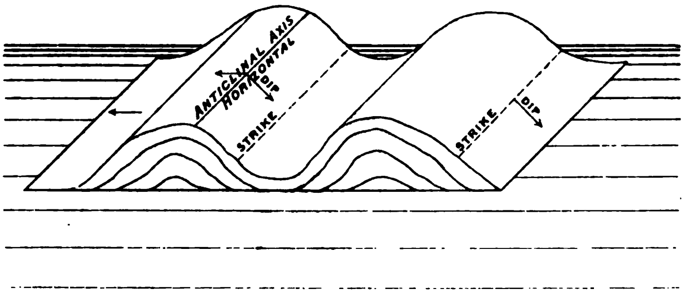


DIAGRAM Nº 3

TO ILLUSTRATE PARALLELISM OF STRIKES WHEN THE ANTICLINAL AND SYNCLINAL AXES ARE HORIZONTAL.



SECTION Nº 7

Williams' drill hole

"Hole Nº 1 Jack diggings opposite 1st hole"

Probable position Plot N.6 E.7 Square 93

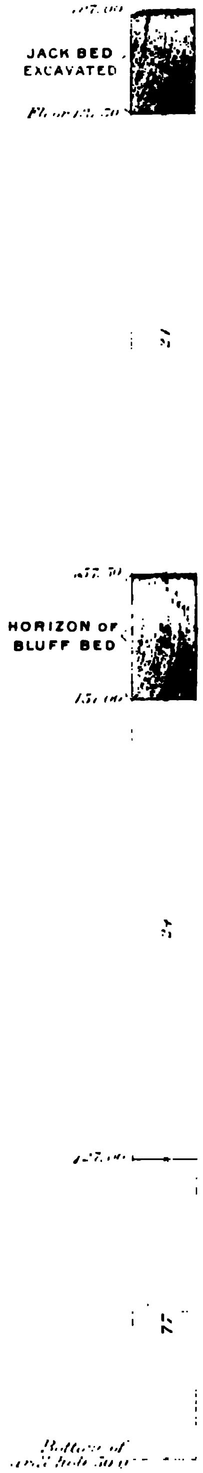
ROCK

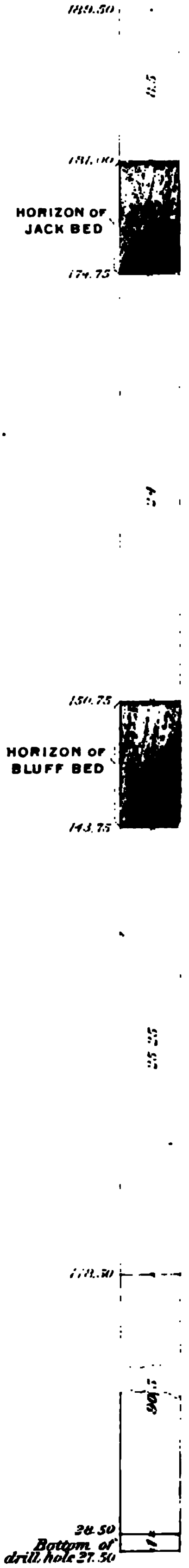
SECTION Nº 6

Williams' drill hole

"Jack diggings offset Hole Nº 2"

Plot N.5 E.6 Square 62 or 63





GEOLOGICAL MEAN
OF COLORS

Sandstones of
Lead bearing group

Sandstones of
Lower sandstone group

Porphyry

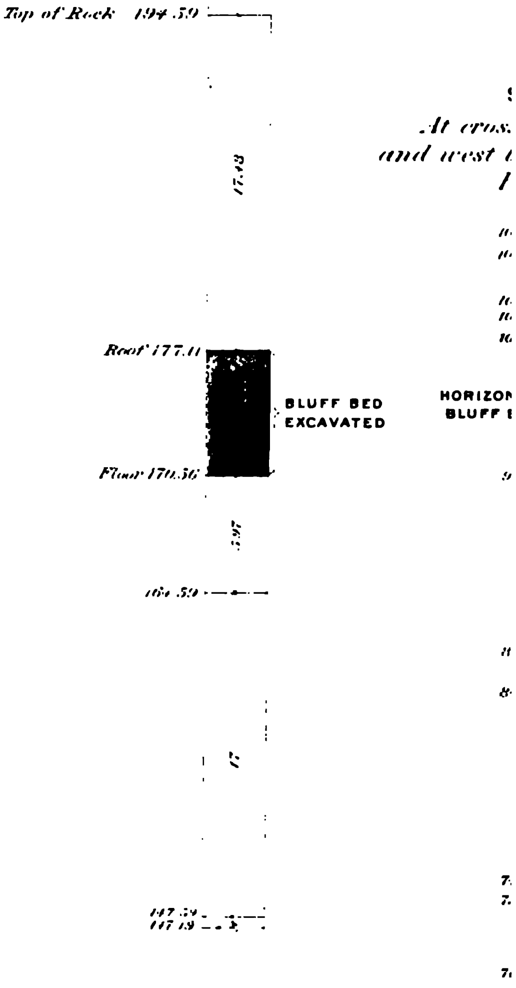
Ore beds

SECTION Nº 2

Williams drill hole Nº 35

Niedner Shaft Bluff diggings

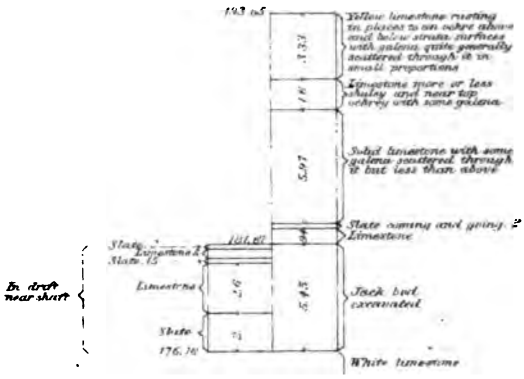
Plot Nº 2 E. 1 Square 31



SECTION Nº 8

Jack diggings

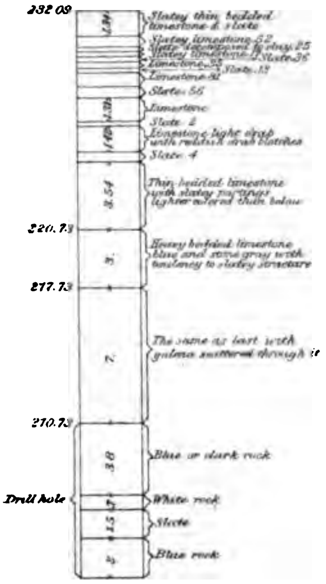
Shaft in Plot N.5 E.6 Square 23


193.05
.133
Yellow limestone rusting in places to an ochre above and below strata surfaces with galena quite generally scattered through it in small proportions
1.8
Limestone more or less shaley and near top ochrey with some galena
5.97
Solid limestone with some galena scattered through it but less than above
Slate coming and going .2
.64
Limestone
181.87
Slate .2
Limestone 2.2
Slate .15
In drift near shaft
Limestone
2.6
5.45
Jack bed excavated
Slate
.74
176.76
White limestone

SECTION Nº 9

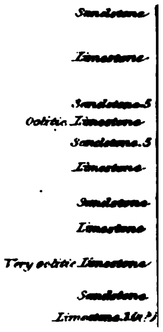
Offset in Rattlesnake diggings

Plot N.4 E.10 Square 70


232.09
Slatey thin bedded limestone & slate
Slatey limestone .52
Slate decomposed to clay .25
Slatey limestone .1
Slate .36
Limestone .35
Slate .13
Limestone .81
Slate .56
Limestone
Slate .2
Limestone light drab with reddish drab blotches
Slate .4
3.54
Thin bedded limestone with slatey partings lighter colored than below
220.73
3.
Heavy bedded limestone blue and some gray with tendency to slatey structure
217.73
7.
The same as last with galena scattered through it
210.73
3.8
Blue or dark rock
Drill hole
White rock
1.5
Slate
Blue rock

Mad
Mine

in



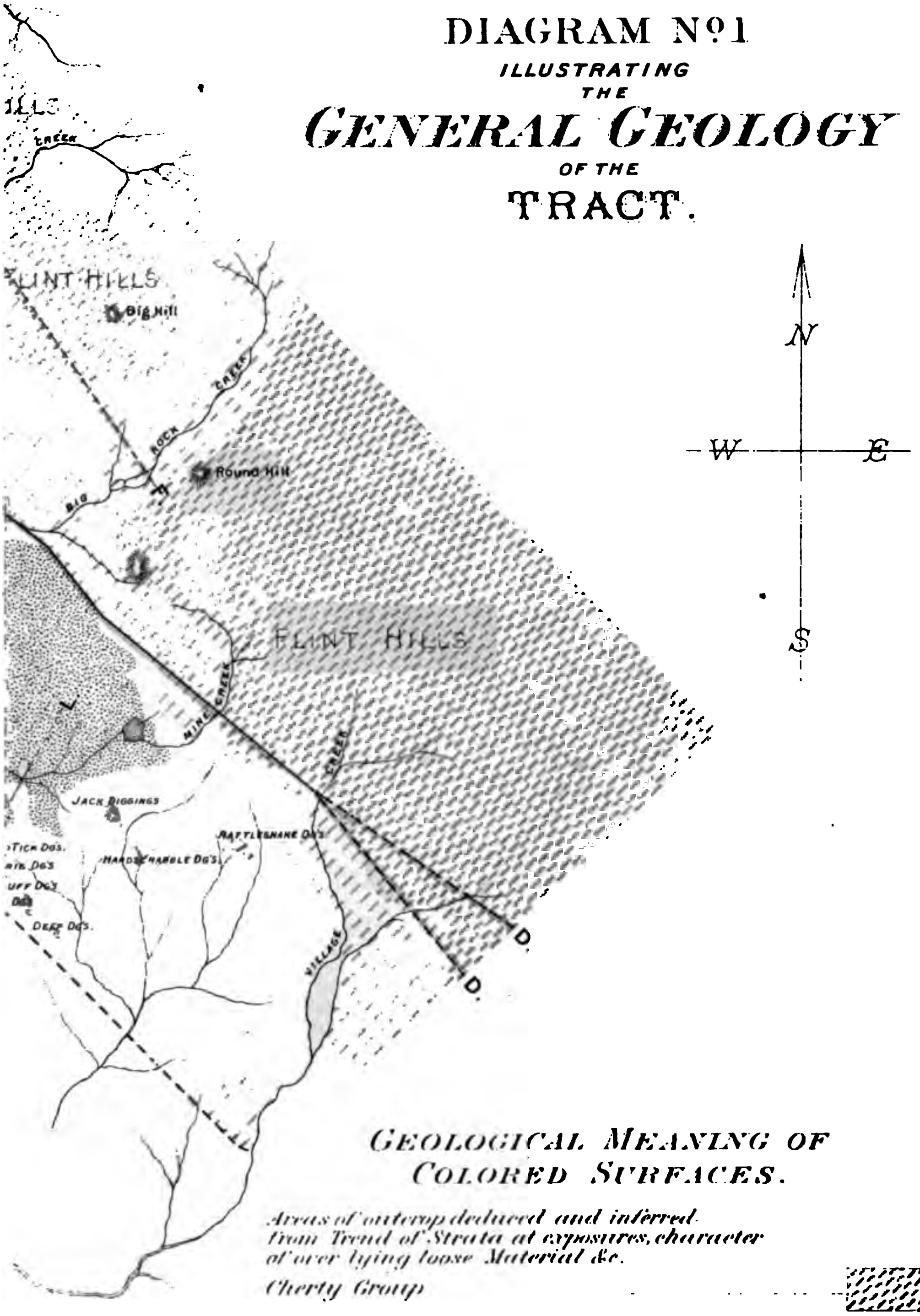
GEOLOGICAL MEANING OF COLORS

Limestones of Lead bearing group	☐
Sandstones of Lead bearing group	■
Sandstones of Lower sandstone group	☐
Porphyry	☐
Ore beds	■

Color for lead bearing group omitted in Sections 2 to 9 except the four feet of sandstone at bottom of group in No. 5 & the Ore beds proper

Vertical scale 10 ft to the inch.

DIAGRAM Nº 1
ILLUSTRATING
THE
GENERAL GEOLOGY
OF THE
TRACT.



GEOLOGICAL MEANING OF COLORED SURFACES.

Areas of outcrop deduced and inferred from Trend of Strata at exposures, character of over lying loose Material &c.

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Massive Magnesian Limestone Group	▨
Lead bearing Group when consisting principally of Limestones	☐
Lead bearing Group when consisting largely of Sand, Ochre and grains of Feldspar	▒
Lower Sandstone Group	☐
Porphyry	☐
Lead Ore exposed naturally or by excavation	■

ICH TO 5,000 FEET

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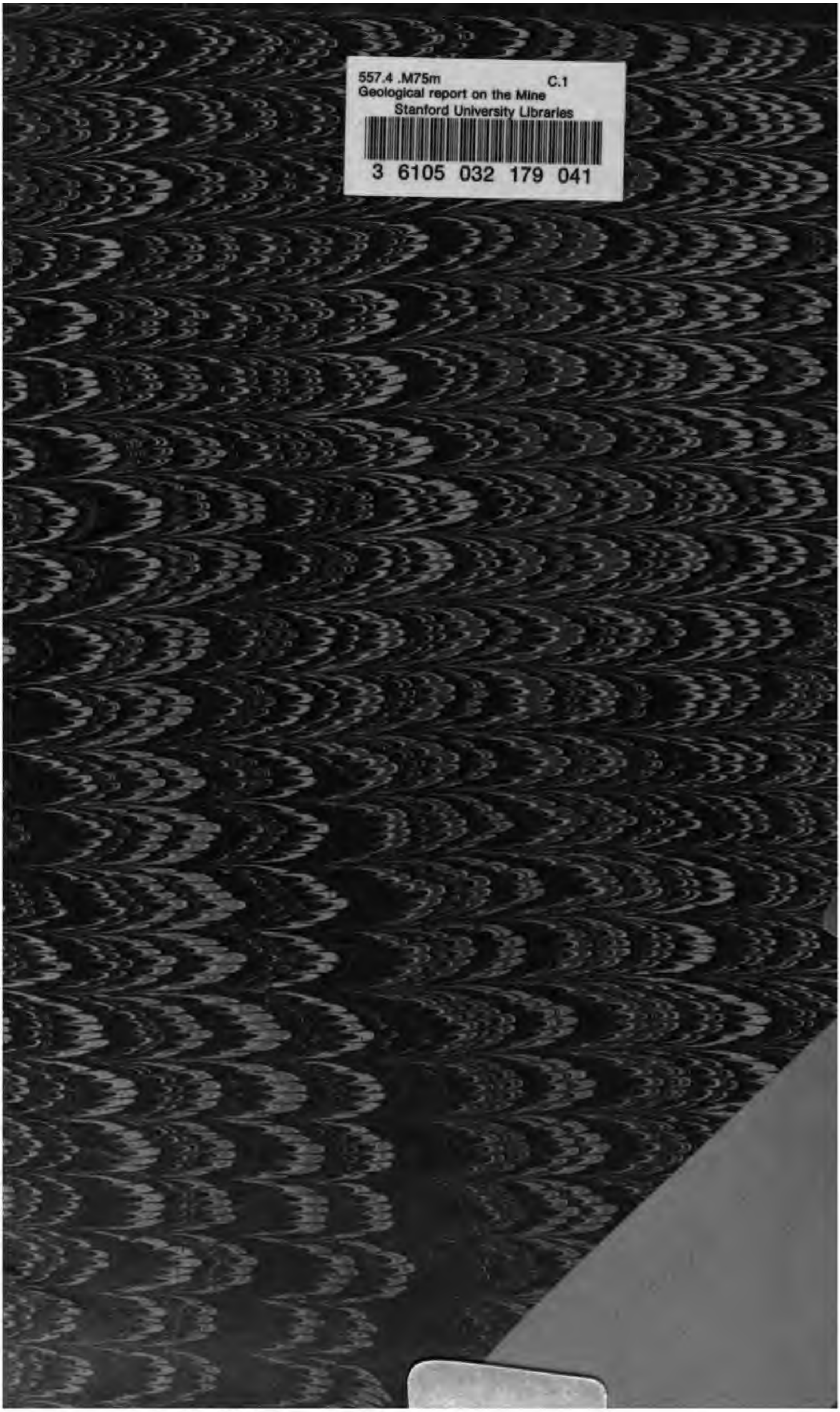
AMES E. MILLS B.S.
CONSULTING GEOLOGIST



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